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PROCEEDINGS OF THE WORLD SYMPOSIUM ON WARM-WATER POND FISH CULTURE

ACTES DU SYMPOSIUM MONDIAL SUR LA PISCICULTURE EN ÉTANG A TEMPÉRATURE ÉLEVÉE

ACTAS DEL SIMPOSIO MUNDIAL SOBRE PISCICULTURA EN ESTANQUES DE AGUA TEMPLADA

Rome, 18-25 May 1966
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ROME, 1968

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Rome, Italy, 18-25 May 1966
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VOLUME V - REVIEW AND EXPERIENCE PAPERS OF MEETINGS VII, VIII AND IX

VOLUME V - ETUDES SPECIALISEES ET COMPTES RENDUS D'EXPERIENCES DES REUNIONS VII, VIII ET IX

VOLUMEN V - DOCUMENTOS DE INFORMACION Y EXPERIENCIAS DE LAS REUNIONES VII, VIII Y IX

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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ORGANIZACION DE LAS NACIONES UNIDAS PARA LA AGRICULTURA Y LA ALIMENTACION
Rome, March 1968 Rome, mars 1968 Roma, marzo 1968

PREPARATION OF THIS VOLUME

This is the fifth and final volume of the Proceedings of the FAO World Symposium on Warm-water Pond Fish Culture and contains the review and experience papers contributed to Meeting VII (on Weed Control), Meeting VIII (on New Systems and New Fishes for Culture) and Meeting IX (on Diseases and Parasites).

The first volume contained the report of the Symposium; the second volume the regional and country reports; the third volume the review and experience papers contributed to Meeting II (on Fertilization and Role of Soil in Fish Pond Productivity) and Meeting III (on Feeds and Feeding), and the fourth volume the review, experience and working papers contributed to Meeting IV (on Breeding and Selection), Meeting V (on Biological and Other Methods of Increasing Production) and Meeting VI (on Standardization of Research Techniques).

The views expressed in the contributions are those of the authors and not necessarily of the Food and Agriculture Organization of the United Nations.

Dr. (Mrs.) Rosemary McConnell and Dr. Homer Swingle assisted in the editing of some of the contributions.

PREPARATION DU PRESENT VOLUME

Le présent volume est le cinquième et dernier des Actes du Symposium mondial FAO sur la pisciculture en étang à température élevée. Il contient les études spécialisées et les comptes rendus d'expériences présentés à la Réunion VII (Lutte contre les plantes aquatiques), à la Réunion VIII (Nouveaux systèmes et nouveaux poissons de pisciculture) et à la Réunion IX (Maladies et parasites).

Le premier volume contient le rapport du Symposium; le deuxième les rapports régionaux et nationaux; le troisième les études spécialisées et les comptes rendus d'expériences présentés à la Réunion II (Fertilisation des étangs et rôle du sol dans la productivité) et à la Réunion III (Aliments pour poissons et alimentation artificielle), et le quatrième les études spécialisées, les comptes rendus d'expériences et les documents de travail présentés à la Réunion IV (Reproduction et sélection), à la Réunion V (Méthodes biologiques et autres d'accroissement de la production) et à la Réunion VI (Normalisation des techniques de recherche).

Les opinions exprimées dans les communications sont celles des auteurs et ne représentent pas nécessairement celles de l'Organisation des Nations Unies pour l'alimentation et l'agriculture.

Mme. Rosemary McConnell et M. Homer Swingle ont collaboré à la mise au point de certaines des communications.

PREPARACION DE ESTE VOLUMEN

Este es el quinto y último volumen de las Actas del Simposio Mundial de la FAO sobre Piscicultura en estanques de agua templada, y contiene los documentos de información y de experiencias que fueron presentados a la Reunión VII (Lucha contra las malas hierbas); a la Reunión VIII (Nuevos sistemas y nuevos peces de cultivo) y a la Reunión IX (Enfermedades y parásitos).

El primer volumen contiene el Informe del Simposio; el segundo, los informes regionales y nacionales; el tercero los documentos de información y de experiencias presentados a la Reunión II (La fertilización y la función del suelo en la productividad de la estanicultura) y a la Reunión III (Tipos de alimentos y métodos de alimentación), y el cuarto los documentos de información, de experiencias y de trabajo presentados a la Reunión IV (Cría y selección), a la Reunión V (Métodos biológicos y de otro orden para aumentar la producción) y a la Reunión VI (Normalización de las técnicas de investigación).

Las opiniones expuestas en los documentos presentados son las de los autores de los mismos y no reflejan necesariamente las de la Organización de las Naciones Unidas para la Agricultura y la Alimentación.

La doctora Rosemary McConnell y el doctor Homer Swingle colaboraron en la redacción editorial de algunos de estos documentos.

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WEED CONTROL IN FISH PONDS IN THE UNITED STATES

by

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Abstract

A brief review has been made of existing information on control of aquatic weeds in fish ponds in the U.S.A. Species of aquatic vegetation commonly found in ponds and methods of control are discussed. Preventative, fertilization, biological, mechanical and chemical methods of control are discussed, along with results and problems encountered when using each method. A few of the herbicides currently used in aquatic weed control are discussed individually along with factors important to the biologist, such as the weed species controlled, toxicity to fish and mammals, etc. Table I in the Appendix lists suggested control measures for some of the common aquatic weeds in fish ponds of the U.S.A.

LUTTE CONTRE LA VEGETATION ENVAHISSANTE DANS LES ETANGS DE PISCICULTURE AUX ETATS-UNIS

Résumé

Il s'agit d'un tour d'horizon rapide des données dont on dispose sur la lutte contre la végétation aquatique dans les étangs de pisciculture aux Etats-Unis. L'auteur examine les espèces de plantes aquatiques trouvées communément dans les étangs et les méthodes de lutte contre leur envahissement. Il passe en revue les techniques préventives, la fertilisation, et les moyens biologiques, mécaniques et chimiques ainsi que les résultats obtenus et les problèmes rencontrés dans chaque cas. Les mérites individuels de quelques-uns des herbicides couramment employés pour la lutte contre la végétation aquatique sont examinés en même temps que les facteurs importants pour le biologiste tels que l'espèce végétale dont on veut se débarrasser, la toxicité pour les poissons et les mammifères, etc. Au Tableau 1 de l'Annexe, on trouvera une liste des mesures de lutte préconisées relativement à certaines plantes aquatiques courantes dans les étangs de pisciculture des Etats-Unis.

LA LUCHA CONTRA LAS MALAS HIERBAS EN LOS ESTANQUES PISCICOLAS EN LOS ESTADOS UNIDOS

Extracto

Se ha hecho una breve reseña de la información actual sobre la lucha contra las hierbas acuáticas nocivas en los estanques piscícolas de las E.U.A. Se examinan las especies de vegetación acuática que se encuentran corrientemente en los estanques y los procedimientos para luchar contra ellas. Se examinan los métodos de lucha preventivos, de fertilización, biológicos, mecánicos y químicos, así como los resultados y los problemas con que se ha tropezado en la aplicación de cada uno de estos métodos. Se examinan aisladamente algunos de los herbicidas utilizados actualmente en la lucha contra las hierbas acuáticas nocivas, junto con los factores importantes para el biólogo, tales como las especies de hierbas nocivas combatidas, la toxicidad para los peces y mamíferos, etc. En el Cuadro 1 del Apéndice figura una lista de las medidas de lucha propuestas para algunas de las hierbas acuáticas nocivas más corrientes en los estanques piscícolas de los E.U.A.

1 INTRODUCTION

A fish pond presents many challenges to the fisheries biologist. One of the primary problems in pond management is the control of undesirable aquatic plants, which are a nuisance that can become a definite threat to fish production and harvest. No section of the Americas is free of aquatic weeds. More than 130 troublesome species are listed as common aquatic weeds by the Weed Society of America (Timmons, 1962).

Aquatic weeds can provide escape cover for small fish which may eventually overpopulate the pond. The higher plants and algae utilize nutrients in the water and thus compete with the fish population, limiting available fish foods and decreasing the annual production of fish (Summers, 1963). Bennett (1948) found that a dense stand of Potamogeton foliosus in an Illinois pond reduced the surface area 51.2 percent and fish yield 58.1 percent. Similar results were reported by Swingle and Smith (1947) and Lopinot (1963).

Why aquatic plants suddenly appear in a pond separated by miles of dry land from other standing water is sometimes a mystery to the biologist. We know that some seeds, such as the cattail (Typha sp.) are blown by winds. Seeds of other aquatic plants are eaten by birds and passed through the digestive tract undigested, only to fall to the pond bottom and germinate in the next pond visited by the bird. Seeds and parts of plants may be transported from one pond to another by boat, outboard motor, or car. Regardless of how they are transported they soon become established in a new pond.

Years of research have developed adequate temporary reduction and control of aquatic weeds in ponds. Control may be either preventative, mechanical, biological or chemical. For satisfactory control it is often necessary to combine several of these methods. The method or methods of control recommended by the biologist should not be allowed to affect the general ecology or be deleterious to the fish population.

Many biologists believe that aquatic vegetation has a definite role in the development and maintenance of a balanced community. The proportion of plant area to water area necessary for optimum fish production has not been determined. Thus, any type of control should be limited to a nuisance area. It should not attempt to eliminate the aquatic vegetation but should leave those areas that are not a nuisance in their natural state (Mackenthun, 1958). This is an excellent approach to the problem, but the vegetation which remains serves as a source of reinfestation in the pond.

The history of any pond will be affected by the continuing tendency of the land to encroach upon shallow ponds and lakes, decrease their size, and make them more shallow, and eventually return them to dry land (Reed, 1961). Aquatic vegetation, aided by fertile water, plays a prominent role in the gradual filling of a lake. For this reason control becomes essential to a productive body of water. This paper is a review of some of the research on ways to control the ecological cycle of a pond with recommendations by the author as to areas which need further research, and with his interpretation of some of the literature.

2 TYPES OF AQUATIC VEGETATION

To control aquatic weeds the biologist must identify the plant and its growth habits. There are many publications available to assist with identification of plants (Muenscher,1944; Fassett, 1960; Klussman and Lowman, 1963; and Lopinot, 1963). Aquatic plants are usually separated into two major groups, algae and higher plants.

2.1 Algae

Pond algae may be divided into planktonic algae, filamentous algae and higher algae. The excessive growth of plankton, often referred to as "water bloom",may cause the water to appear peasoup-green or brown. Common examples are Microcystis and Anabaena. Filamentous algae commonly known as "pond scum", consist of long, stringy, hairlike strands, green or brown, with a cottony appearance. Examples are *Cladophora* and *Spirogyra*. Higher algae like *Chara* and *Nitella* grow from the pond bottom and resemble higher plants.

2.2 Higher plants

The common higher plants found in, or associated with, ponds may be classified as floating, submersed, emersed and woody shrubs. Floating plants like water hyacinth (*Eichhornia crassipes*), water lettuce (*Pistia stratiotes*) and duckweed (*Lemna* sp.) are not attached to the pond bottom and occur on the surface.

Submersed plants are usually rooted to the bottom and may have flowers or leaves extending to the surface. Examples are pondweeds (*Potamogeton*), *Elodea*, and coontail (*Ceratophyllum demersum*). Emersed plants are rooted to the bottom and grow mostly above the surface. Common examples are cattail (*Typha*), bulrush (*Scirpus*), and spatterdock (*Nuphar advena*). Woody shrubs such as buttonbush (*Cephalanthus*) and willows (*Salix*) cannot be classified as true aquatics but may affect production of ponds.

3 CONTROL METHODS

3.1 Preventative methods

When a pond is constructed, aquatic weed problems should be considered and precautions taken to prevent weeds from establishing in the pond. Lawrence (1949) recommends avoiding depths of less than 3 ft (=0.9 m) around the shoreline. The pond should be located away from pollution drainage, and where it will not receive excessive run-off from fertile farmland. Construction in an area where water will bring heavy loads of silt and soon fill in the parts of the shoreline should be avoided.

There is no practical, permanent, preventative control method (Eipper and Brumsted, 1959), but with proper construction weed establishment can be delayed for several years. Thus, preventative control through proper construction of the pond is strongly emphasized by the American biologist.

3.2 Fertilization

Inorganic fertilizers have for many years been recommended for the control of submersed vegetation in the southeastern United States (Swingle and Smith, 1947). Fertilization causes many microscopic plants to grow in the water, which forms a dense shade and prevents the establishment of underwater weeds by eliminating the sunlight. It must be applied throughout the growing season. Precautions must be taken not to overfertilize, especially during the warmer seasons. Fertilization in ponds has not been recommended elsewhere as a general fish management technique because results have been variable and uncertain (Ball, 1948; Hansen *et al.*, 1960). Once the fertility of pond soil is built up, this fertility can produce a vigorous growth of undesirable algae and aquatic plants (Bennett, 1962). In Michigan (Ball, 1952) and West Virginia (Surber, 1948) fertilization produced heavy growths of algae and higher aquatic plants. Because of variable results, pond fertilization as a method of weed control should be used with caution.

3.3 Biological methods

Experiments have been conducted by the Alabama Agricultural Experiment Station, Auburn University, since 1957, on the use of eight species of herbivorous fish in controlling aquatic vegetation. The tilapia (*Tilapia melanopleura*), grass carp (*Ctenopharyngodon idella*) and the common carp (*Cyprinus carpio*) have proved best (Avault, 1965). Many of the species evaluated are sensitive to cold weather and must be overwintered in troughs in heated rooms (Swingle, 1960). It appears that these fish may be of some value in controlling aquatic weeds in ponds but they are not in themselves the total answer (Shell, 1962). Experiments with *Tilapia* by Pierce and Yawn (1965) did not control aquatic vegetation in Georgia ponds. Davison, Lawrence and Compton (1962) have recommended the use of algae-eating fish in farm ponds.

A large fresh-water snail (Marisa cornuarietis) has shown promise for the control of several species of aquatic weeds in Florida (Seaman and Porterfield, 1961; Blackburn, 1965) and Puerto Rico (Ferguson and Palmer, 1958). The Entomology Research Division of the U.S. Department of Agriculture has introduced a small flea beetle (Agasicles) from South America for control of alligatorweed (Alternanthera philoxeroides) (Hawkes, 1965; Anderson, 1965). Research is being conducted with the Florida manatee (Trichechus manatus latirostris) as a means of controlling aquatic weeds in south Florida drainage canals (Sguros, Monkus and Phillips, 1965). Observations by the Bureau of Reclamation (U.S. Department of Interior) personnel in the State of Washington have indicated that a low-growing species of water plantain (Alisma gramineum) competes effectively with rank-growing pondweeds in large canals (Timmons, 1963). Biological agents as possible control methods for aquatic weeds will play an important role in future research in the Americas. At present their use is limited and will continue to be, until research on how the organism will fit into the ecology of a pond or lake advances.

3.4 Mechanical methods

Hand cleaning of aquatic weeds is the oldest and probably the most frequently used method of control. Many species of emersed aquatics can be pulled out by their roots when the growth starts. Hand raking will clear out algae and submersed weeds growing near the shoreline. Removal by hand only controls temporarily but is economical, and effective for a short period. Most of the time it requires a diligent program, and more often than not the weeds grow faster than they can be removed by hand.

Motor-powered weed cutters help to control aquatic vegetation. From 1900 to 1955 the U.S. Army Corps of Engineers (Wunderlich, 1962; Zeiger, 1962) used various types of mechanical methods such as crushers, sawboats, and harvesters to control the troublesome water hyacinth in the South. Lange (1965) described a sickle-bar cutter, utilized for the harvest of submersed weeds in many areas of the United States. These underwater cutters cut the vegetation three to five ft below the water surface; leave it, or convey it onto a barge.

Mechanical weed control is like mowing a lawn, it must be done frequently through the growing season. It has not proven to be the complete answer, and may spread the infestation. The present trend is to replace these methods with chemical methods, more effective, convenient, and economical.

Lantz, Davis and Hughes (1964) used the fluctuation of water levels in large lakes and ponds as a control. In lakes that have had a fluctuating level for three years or more the submersed vegetation has been reduced 90 percent. The effect on fish population has been an increase in game fish of harvestable size.

3.5 Chemical methods

Chemicals (herbicides) can effectively control many species of aquatic weeds in ponds and along shorelines, provided that the biologist knows the weed species, the appropriate herbicide, recommended rate, the time of treatment, and the water volume or area to be treated.

Research has lagged considerably behind terrestrial weed control in the Americas. The discovery of 2,4-D (2,4-dichlorophenoxyacetic acid) in 1944 did not however have the pronounced effect that it had on terrestrial weed control. The need for aquatic weed research in the U.S.A. was recognized in 1957 when the U.S. Department of Agriculture (Agricultural Research Service) increased its staff from three to nine working scientists (Timmons, 1963). The same year a contract was negotiated with Auburn University (Auburn, Alabama) to evaluate 750 chemical compounds as herbicides on submersed weeds and to check 100 of the most promising for toxicity to representative species of fish (Lawrence *et al.*, 1961). Out of this increased research effort came many of the new herbicides now under study.

The development of new techniques for evaluating such herbicides has made a number of new herbicides available, all developed specifically for aquatic weed control (Frank, Otto and Bartley, 1961; Blackburn, 1963). However, as with methods already discussed, control may be no more than temporary. Occasionally, a single application will eliminate pond weeds, but this is the exception rather than the rule. Research shows that the method depends on the habitat. Weeds in static water require herbicides at a lower concentration than do those in moving or flowing water. If vegetation is dense, small areas should be treated at intervals to avoid oxygen depletion. Herbicides toxic to fish can be used only during renovation of the pond.

Herbicides have not thus far been used as a preventative but only after weeds appear. Research now underway on pre-emergent herbicidal applications may change this situation. A few of the more important herbicides for control of aquatic weeds are discussed below. Factors of particular importance to the biologist are mentioned and Table I of the Appendix presents in a condensed form some of the control measures used for many of the common aquatic weeds in the U.S.A.

3.5.1 Copper sulphate

Bluestone or blue vitriol is very effective against most species of algae, including Chara. It is probably the oldest, most economical, and most widely used chemical for the control of algae. Its use was first advocated in the U.S.A. by Moore and Kellerman (1904). Steyn (1944) reported that Microcystis can be eradicated by the use of 0.8 parts per million by weight (ppmw) of copper sulphate. Rates of 0.1 to 1 ppmw are usually adequate, but some of the more resistant species require more applications.

Studies have shown that a single application of copper sulphate has no adverse effects on the abundance of zooplankton (Crance, 1963). Snow (1956) reported Pithophora difficult to kill with copper sulphate; in areas where applications were repeated bluegill (Lepomis macrochirus) production was reduced because of a reduced plankton population in the pond. Problems have been encountered in areas where the water has a methyl orange alkalinity greater than 50 ppm. The water high in carbonates caused an insoluble precipitate of copper to form, and thus reduced its algicidal properties. In such areas high concentrations of copper sulphate are required.

Copper sulphate is the only algicide that is approved for use in drinking water (Palmer, 1962). The U.S. Public Health Service has ruled that water containing not over 2.5 ppmw of copper sulphate is satisfactory for human consumption. Concentrations up to 100 ppmw have been found safe in drinking water for 2-year old cattle (Klingman, 1961).

3.5.2 Sodium arsenite

This has been used to control aquatic weeds in Wisconsin lakes since 1926 (Mackenthun, 1958). Floating algae and submersed and floating aquatic plants are generally susceptible. One of our first aquatic herbicides, it is still used more extensively in our ponds and lakes than any other. Some biologists consider it the best all-round and cheapest herbicide available (Mackenthun, 1950). In spite of its proven effectiveness under a wide range of conditions, it has always had the inherent drawback of toxicity to mammals (one-fifth gram may kill a man). Because of its toxicity the exposed skin of the operator must be protected. Water with more than 0.05 ppm arsenic is considered unsafe for drinking. It is safe for fish at rates recommended for aquatic weed control.

Lawrence (1958) reported that 4 ppmw of sodium arsenite would control most species of submersed weeds and algae in farm ponds. However, he had reported earlier that 4 ppmw substantially reduced bluegill production, and attributed this to the destruction of microcrustaceae and reduction of bottom organisms in the ponds. Most fish will withstand up to 12 ppmw of arsenic (Na_3AsO_3).

3.5.3 2,4-D and 2,4,5-T

The discovery of 2,4-D (2,4-dichlorophenoxyacetic acid) in 1944 had an immediate effect on terrestrial weed control. Tried first on the water hyacinth, it was very effective at rates of 2.3 to 4.6 kg/ha (Zimmerman, et al., 1950). Scientists quickly discovered that applying 2,4-D and 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) to the foliage of aquatic plants did not kill below-water portions because these herbicides translocate very poorly in aquatic plants.

Grigsby, Hamilton and Smith (1956) reported a new technique, using a 2,4-D impregnated pellet for the control of rooted submersed weeds. The use of granular 2,4-D at 11.4 to 22.8 kg acid equivalent per ha has partially controlled coontail, southern naiad (Najas guadalupensis), Elodea, spatterdock, milfoil (Myriophyllum), and other aquatics in some areas of the U.S.A. Recent research in Louisiana has indicated that a combination of 2,4-D and diglycolic acid will control most species of submersed weeds (Solymosy and zurBurg, 1965).

Pure 2,4-D acid in 100 ppmw concentration, has been observed to kill some fingerling fish. However, fingerling bluegills have been killed with rates as low as 1 to 5 ppmw of the butyl ester of 2,4-D. Esters are oil-soluble, and oils are known to be toxic to fish.

Both 2,4-D and 2,4,5-T have been used to control shrubs and trees around shorelines. 2,4,5-T is especially effective against woody plants such as brambles, vines, and shrubs. These plants are often difficult to control with 2,4-D. The ester formulations applied in oil often are more effective on hard-to-kill plants.

3.5.4 Silvex

2-(2,4,5-trichlorophenoxy) propionic acid is a phenoxy herbicide, effective against many species of aquatics, shrubs, and trees. Younger (1958) showed that in New Jersey most submersed weeds except pondweeds could be controlled with silvex at 0.5 to 2.5 ppmw. Similar results have been obtained in Oklahoma (Houser and Gaylor, 1961) and in Georgia (Thomaston, Pierce and Wyatt, 1960) farm ponds. Silvex has proved to be the most effective herbicide on alligator weed in Florida (Weldon, Blackburn and Seaman, 1961). It is also effective on various waterlilies, spikerush (Eleocharis), milfoil, and on most species of submersed weeds. However, certain restrictions on its use in waters of high pH or total hardness along with a contact time of two to three weeks has reduced its use for the control of this major aquatic group.

The herbicide may be sprayed on emergent leaves or injected into the water. Recommended rates depend on the species treated. Silvex, nonpoisonous to livestock, is nontoxic to fish at rates of 5 ppmw, but it may render fish in treated ponds unpalatable for some time after treatment (Surber, 1961).

3.5.5 Dalapon

2,2-dichloropropionic acid is especially effective on grasses and grasslike plants such as cattails and maidencane (Panicum hemitomon) but has no effect on broad-leafed plants. Many species are most susceptible if rooted in water less than six inches (15.2 cm) deep. It has been found to be safe to fish at concentrations up to 3,000 ppmw.

Cattails have been effectively controlled at rates of 5.7 to 11.4 kg/ha (Timmons et al., 1963). Equivalent rates have controlled many species of aquatic grasses. Dalapon applied in a five percent solution of emulsified diesel oil has been effective on difficult-to-control species of cattail in Florida (Blackburn and Weldon, 1963).

3.5.6 Endothall

7-oxabicyclo (2.2.1) heptane-2,3-dicarboxylic acid has proved very effective on many species of aquatic weeds in ponds where the contact time is seven or more days (Blackburn and Weldon, 1964). Walker (1961) found it to be safe to fish and fish food organisms at recommended rates. It is utilized in aquatic weed control as granular and liquid formulations. The tertiary fatty acid formulations (mono- and di-N,N-dimethylcocoamine) of endothall have shown outstanding activity on submersed weeds (Blackburn and Weldon, 1964).

McLarty (1961) found that a granular formulation of these two herbicides was very effective on Cladophora in the Great Lakes area. The big problem with these two herbicides is their toxicity to fish (0.25 ppmw), which has restricted their use to treating small areas of the pond, or where a complete pond renovation is recommended.

3.5.7 Amitrole

3-amino-1,2,4-triazole is effective on several species of aquatics. Seaman (1961) found that water hyacinth could be controlled with 1.2 kg/ha of amitrole-T (amitrole plus sodium thiocyanate). Amitrole applied at 5.7 to 11.4 kg/ha will control cattail, grasses and sedges. Like Dalapon it is harmless to fish, but not approved for areas where livestock may drink the water or the water is used for irrigation.

3.5.8 Diquat and Paraquat

Diquat (6,7-dihydrodipyrido /1,2a:2',1'-c/ pyrazidiinium salt) and paraquat (1,1'-dimethyl-4,4'-bipyridinium salt) have received considerable attention as aquatic herbicides in the U.S.A. since 1959 and throughout the world since 1962. In 1961 Blackburn, Seaman and Weldon reported them as outstanding against many species. After four years of field evaluation in Florida, Blackburn and Weldon (1964) reported that these two bipyridyl herbicides were the most effective of some 13 herbicides evaluated on submersed weeds. Some species of submersed weeds can be controlled at rates of 0.2 ppmw. Rates of 1.2 kg/ha have controlled water lettuce, water hyacinth and other floating weeds (Weldon, Blackburn and Seaman, 1963).

Lawrence et al. (1963) reported that these two herbicides are safe for fish at concentrations much greater than those recommended for aquatic weed control. Research has also indicated that Diquat has no adverse effects on plankton or fish food organisms (Tatum and Blackburn, 1963). The herbicides are highly water-soluble and easy to apply to a pond. Their greatest disadvantage is that they cannot be used in ponds containing suspended soil or organic particles, because the herbicidal activity may be lost by adsorption to the soil or organic matter.

The research effort spent during the past five years on these two herbicides for use in aquatic weed control probably surpassed that spent on any other herbicide. The decision to utilize this research information was made by the American producer in 1964, when he stressed development of Diquat (Mackenzie, 1965). The main reason for this decision was the long persistence of Paraquat in treated ponds (Coats et al., 1964). Research had indicated little difference in the aquatic herbicidal activity of the two herbicides, except for the superiority of Paraquat for use on emergent aquatic vegetation.

3.5.9 Aromatic solvents

These have been very effective against species of submersed weeds in ditches and canals of the Western U.S.A. (Bruns et al., 1955). Aromatic solvents are very toxic to fish, crayfish, snails and plankton (Stephens et al., 1952). These chemicals, even at very low concentrations, usually kill fish. Because of their toxicity to aquatic life they have never been recommended for ponds.

3.5.10 Acrolein

Acrolein (acrylaldehyde) has been used for the control of submersed weeds and disease-carrying snails (van Overbeek, Hughes and Blondeau, 1959). It is very effective against the more resistant aquatics, such as elodea and pondweeds. Being a potent irritant and lachrymotor, special equipment is required for its application. It is very toxic to fish and other aquatic organisms, making it a seldom used herbicide in ponds. However, in large lakes it can be used if precautions are taken to treat small areas at a time which permits the fish to move out of the treated area.

3.5.11 Diuron and Simazine

During the past few years Diuron (3-[3,4-dichlorophenyl]-1,1-dimethylurea) and Simazine (2-chloro-4,6-bis[ethylamino]-s-triazine) have received considerable research attention as algicides for use in fish hatcheries and farm ponds. Experiments conducted by the U.S. Department of Interior (Sills, 1964) have shown that Diuron applied at rates of 1.2 kg/ha will control many of the filamentous algae. In the same experiments up to 3.6 kg/ha had no adverse effects on fish and fish food organisms. Jordan, Day and Hendrixson (1962) obtained similar results in California with diuron. Applications of 1 ppmw of Simazine have controlled most species of algae in hatchery ponds (Snow, 1963). Research on these two herbicides is being intensified to determine if they can be recommended for algae control in ponds.

3.5.12 Dichlobenil and Fenac

A different approach has recently been initiated to determine whether or not certain herbicides can be used to treat the pond bottom before weed growth starts. Dichlobenil (2,6-dichlorobenzonitrile) and Fenac (2,3,6-trichlorophenylacetic acid) have shown promise for this type of preventative control in ponds (Pierce, Frey and Yawn, 1965). Older ponds have been drained during the winter months, and the exposed pond bottom treated. After treatment the pond is refilled to the normal level.

3.5.13 Miscellaneous herbicides

Dichlone (2,3-dichloro-1,4-naphthoquinone) has been recommended for the control of some algae (Lopinot, 1963). The toxicity of dichlone for algae is very near that for fish, and so its use as an algicide has not been widely recommended by biologists.

Dehydroabiethylamine acetate has been used to control some of the branched algae but due to its toxicity to young fish and the cost of repeated treatments required, it has not been widely used as an algicide (Snow, 1956).

Bond, Lewis and Fryer (1959) considered paradiisobutyl phenoxy ethoxy ethyl dimethyl benzylammonium chloride a promising herbicide for the control of elodea in ponds. They found it to be toxic to elodea at 2 ppmw and safe for fish at higher concentrations.

4 THE FUTURE FOR AQUATIC WEED CONTROL AND RESEARCH

The future of aquatic weed control and research looks bright and promising in the Americas. There is increased interest in controlling aquatic vegetation. Recreation is part of the American way of life, and water areas are part of the recreational concept. As our population expands, our need for water increases. That portion of our water resources lost or deemed unusable because of aquatic weeds is becoming more acute each year. State and Federal agencies are faced with the problem of wise and conservational management of our water resources.

Even with this bright outlook, many problems are left to the researcher. Manpower, facilities and other resources necessary for research are limited. The relatively easy problems of research have been solved to a great extent, but the complex problems of the effect of herbicides on aquatic environment still leave a big gap in our knowledge. The effect of herbicides on fish and wildlife and on crops irrigated with the water; the problem of residues of herbicides in water and their effect on aquatic soil, fish and game; and the possible contamination of public water supplies, must be considered if chemical control is to be widely accepted. Public resistance is expected to increase and if chemical control is to advance, we must solve these problems. The United States Congress realizes that these questions must be answered, and it has provided funds for research on pesticides. American chemical manufacturers have joined in by increasing their research staffs in basic pesticide research.

Although research effort on biological control has increased in recent years, it is expected to increase at a much greater rate. Biological control agents will probably play a much more important role. The research now being conducted on the use of insects, herbivorous fishes, snails and other biological means may prove of great value to the biologist.

Future research must place greater emphasis on the morphology, physiology and life cycle of the aquatic plant. Although mechanical methods have been replaced, we can still utilize them. We must leave no stone unturned in our search for the answer to the complex problem.

As the biologist directs his control program towards eradication he must remember that man has seldom eradicated a plant. The best results will probably be obtained by taking advantage of natural environment through plant competition and biotic balance. These should be supplemented by a diligent herbicidal and management program.

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6 APPENDIX

Table I

Suggested control measures for common aquatic weeds in fish ponds[1]

	Control measure		
Weed	Herbicide	Rate of application	Remarks
ALGAE			
PLANKTON: (Microcystis, Anabaena, and Aphanizomenon)	Copper sulphate	0.25 ppmw	soft water
	"	1.00 ppmw	hard water
	Dichlone	0.5 ppmw	
FILAMENTOUS: (Spirogyra, Oedogonium, Hydrodictyon, Pithophora, and Cladophora)	Copper sulphate	0.5-1.0 ppmw	soft water
	"	0.1-2.0 ppmw	hard water
	Dichlone	0.15 ppmw	
	Endothall (amine salt)	0.25-1.0 ppmw	Toxic to fish
	Sodium arsenite	4 ppmw	Caution: Toxic to mammals
	Algae-eating fish		
HIGHER ALGAE: (Chara and Nitella)	Copper sulphate	1-2 ppmw	soft water
	"	2-3 ppmw	hard water
	Sodium arsenite	4 ppmw	Caution: Toxic to mammals
FLOATING WEEDS			
duckweeds	Diquat	0.25-1 ppmw	Do not apply in muddy water
(Lemna, Spirodela, and Wolffia)	fuel oil	2.5 hl/ha	Spray over surface
water hyacinth (Eichhornia)	2,4-D(amine salt)	2.3-4.6 kg/ha	Foliar spray
	2,4-D(low volatile ester)	2.3-4.6 kg/ha	"
	Diquat	1.3 kg/ha	"
	Silvex	2.3-4.6 kg/ha	"
	Amitrole-T	1.3-1.8 kg/ha	"
water lettuce (Pistia) and salvinia (Salvinia)	Diquat	1.3 kg/ha	"

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[1] These suggested control measures are not necessarily those recommended by the author but are a review of U.S.A. methods

Table I (continued)

Weed	Control measure		Remarks
	Herbicide	Rate of application	
SUBMERSED WEEDS[2/]			
elodea (*Elodea*)	Diquat	0.5-1.5 ppmw	Do not apply in muddy water
	Endothall(amine salt)	0.25-1.5 ppmw	Toxic to fish
	Sodium arsenite	4-6 ppmw	Caution: Toxic to mammals
coontail (*Ceratophyllum*)	Diquat	0.5-1 ppmw	Do not apply in muddy water
	Endothall	1-2 ppmw	
	Endothall(amine salt)	0.25-1 ppmw	Toxic to fish
	Silvex	1.5-3 ppmw	
	2,4-D (ester)	3-5 ppmw	
	Sodium arsenite	4-6 ppmw	Caution: Toxic to mammals
naiad (*Najas*)	Diquat	0.25-1 ppmw	Do not apply in muddy water
	Endothall	1-2 ppmw	
	Endothall(amine salt)	0.25-1 ppmw	Toxic to fish
	Sodium arsenite	4-6 ppmw	Caution: Toxic to mammals
	Silvex	2-3 ppmw	
widgeon grass (*Ruppia*)	Diquat	0.5-1.5 ppmw	Do not apply in muddy water
pondweed (*Potamogeton*)	Diquat	1-2.5 ppmw	Do not apply in muddy water
	Endothall	1.5-3 ppmw	
	Endothall (amine salt)	0.5-1.5 ppmw	Toxic to fish
	Silvex	2.5-4 ppmw	
	Sodium arsenite	4-7 ppmw	Caution: Toxic to mammals
milfoil (*Myriophyllum*)	2,4-D (ester)	2-4 ppmw	
	Silvex	2-4 ppmw	
	Diquat	0.5-1.5 ppmw	Do not apply in muddy water
fanwort (*Cabomba*)	Sodium arsenite	4 ppmw	Caution: Toxic to mammals
	2,4-D	3-5 ppmw	
bladderwort (Utricularia)	Diquat	0.5-1.5 ppmw	Do not apply in muddy water
	Silvex	2.5-4 ppmw	

[2/] Fertilization (eliminating sunlight) is used as a preventative method of control for most submersed weeds in the southeastern U.S.A.

Table I (continued)

Weed	Control measure		Remarks
	Herbicide	Rate of application	
EMERSED WEEDS			
cattail (Typha)	Dalapon	5.7-11.4 kg/ha	Foliar spray
	Dalapon + diesel oil (emulsifiable)	5.7-11.4 kg/ha + 1 hl/ha	Foliar spray
	Amitrole	5.7-11.4 kg/ha	Foliar spray
	underwater cutting		
arrowhead (Sagittaria)	2,4-D(low-volatile ester)	4.6-9.2 kg/ha	Foliar spray
	Silvex (low-volatile ester)	4.6-9.2 kg/ha	Foliar spray
alligatorweed (Alternanthera)	Silvex (low-volatile ester)	9.2 kg/ha	Foliar spray
	Silvex (granular)	34.2 kg/ha	Broadcast over weed
waterlily (Nymphaea) and spatter dock (Nuphar)	2,4-D	2-4 ppmw	Spray over surface or inject underwater
	Silvex	2-4 ppmw	
	2,4-D (granular)	34.2 kg/ha	
	Silvex + endothall	2ppmw + 2 ppmw	
	underwater cutting		4-6 cuttings/year
smartweed (Polygonum)	2,4-D (low-volatile ester)	4.6-9.2 kg/ha	Foliar spray
	Silvex (low-volatile ester)	4.6-9.2 kg/ha	Foliar spray
WOODY PLANTS			
willows (Salix)	2,4-D (low-volatile ester)	4.6-9.2 kg/ha	Foliar applic.water or oil
	2,4,5-T (low-volatile ester)	4.6-9.2 kg/ha	Foliar applic.water or oil
	Silvex (low-volatile ester)	4.6-9.2 kg/ha	Foliar applic.water or oil
	Picloram	2.3-4.6 kg/ha	Applied in water
buttonbush (Cephalanthus)	Silvex (low-volatile ester)	9.2 kg/ha	Applied in oil or water
	Picloram	2.3-4.6 kg/ha	Applied in water

Table II

List of Herbicides

Common names	Chemical name or description
Acrolein	acrylaldehyde
Amitrole	3-amino-1,2,4-triazole
Amitrole-T	3-amino-1,2,4-triazole-ammonium thiocyanate
Aromatic solvents	emulsifiable mixtures of xylene-type solvents
Sodium arsenite	Na_3AsO_3
Copper sulphate	$CuSO_4$
Dalapon	2,2-dichloropropionic acid
Dichlobenil	2,6-dichlorobenzonitrile
Dichlone	2,3-dichloro-1,4-naphthoquinone
Diquat	6,7-dihydrodipyrido (1,2-a:2'1'-c) pyrazidiinium salt
Diuron	3-(3,4-dichloropheny 1)-1,1-dimethylurea
Endothall	disodium or dipotassium salt of 7-oxabicyclo-(2.2.1) heptane-2,3-dicarboxylic acid
Amine salt	mono-N,N-dimethylococoamine salt of 7-oxabicyclo-(2.2.1) heptane-2,3-dicarboxylic acid

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WEED CONTROL IN FISH PONDS IN THE NEAR EAST

by

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WEED CONTROL IN FISH PONDS IN THE NEAR EAST

Abstract

Weeds occurring in fish ponds in the Near East Region are classified according to their ecological characteristics. Mechanical, chemical and biological methods of control of the weeds are described. The mechanical methods of control which were the most common in the past have declined because of inefficiency and the increasing cost of labour.

Herbicides which at present are widely used in the region have been found effective and economical.

Biological control, when possible, has advantages over the other methods, as generally it results in increased production directly and does not affect the fauna or flora in the ponds and surrounding areas, as some of the herbicides do.

LUTTE CONTRE LA VEGETATION AQUATIQUE DANS LES ETANGS DE PISCICULTURE AU MOYEN-ORIENT

Résumé

Cette communication contient une classification des plantes aquatiques rencontrées dans les étangs de pisciculture de la région du Moyen-Orient, établie en fonction de leurs caractéristiques écologiques. L'auteur décrit des méthodes de lutte mécaniques, chimiques et biologiques. Les procédés mécaniques de lutte, qui étaient les plus courants dans le passé, ont vu leur importance décroître en raison de leur inefficacité et du coût croissant de la main-d'oeuvre.

Les herbicides, dont l'usage est largement répandu dans la région, se sont avérés efficaces et économiques.

La lutte biologique, lorsqu'elle est possible, présente des avantages par rapport aux autres méthodes étant donné qu'en général elle a pour effet d'accroître directement la production et n'exerce aucune influence défavorable sur la faune ou la flore des étangs et des régions avoisinantes, comme le font certains herbicides.

LA LUCHA CONTRA LAS MALAS HIERBAS EN LOS ESTANQUES PISCICOLAS DEL MEDIO ORIENTE

Extracto

Las malas hierbas que se encuentran en los estanques piscícolas de la región del Medio Oriente se clasifican según sus características ecológicas. Se describen métodos de lucha mecánicos, químicos y biológicos contra dichas hierbas. Los métodos mecánicos de combate que fueron los más corrientes en tiempos anteriores han cedido a causa de su ineficacia y del costo cada vez mayor de la mano de obra. Se han comprobado que resultan eficaces y económicos los herbicidas que en la actualidad se utilizan ampliamente en la región.

Cuando ello es posible la lucha biológica presenta ventajas sobre los demás métodos ya que, generalmente, determina un aumento directo de la producción y no influye en la fauna o flora de los estanques y zonas adyacentes como ocurre con algunos herbicidas.

1 INTRODUCTION

There are several ways in which weeds may affect the production of fish in ponds. Dense vegetation restricts the movements of fish and limits the availability of living space. Floating plants such as Nuphar luteum sometimes completely cover the pond surface and prevent proper aeration. The weeds assimilate a large proportion of the soluble nutrients in ponds and thereby affect the production of plankton required as fish food. Some weeds such as Phragmites communis and Typha angustata trap and collect large quantities of silt and organic peat around their roots and stems, which within a few years cause a considerable part of infested ponds to fill up. An assessment of the effect of weeds on fish production may be made by comparing the yields of ponds before and after weed control. It has been shown that ponds heavily infested with submerged weeds like Potamogeton sp. and Ceratophyllum demersum, yielding only 600 to 700 kg/ha, produced 2,000 kg of fish per hectare after the weeds were eradicated by the application of sodium arsenite. Similar results have also been obtained by controlling the growth of Phragmites and Typha.

Plant species which are specific to the same depth of water form a vegetation zone characteristic of that particular depth of water in similar ponds. There is a certain amount of overlapping at the margins of the zones, but each zone may be distinguished by its dominant species.

The observations and experiments described in this paper were made in Israel, but the plant successions are similar in other parts of the Near East.

2 VEGETATION ZONES IN FISH PONDS

2.1 Bank zone

Plants which grow in this zone do not invade the water. The more common species are: Inula viscosa, Inula crithmoides, Conyza dioscoridis, Imperata cyclindrica, Erianthus rarennae, Epilobium hirsutum, Lycopus europeus, Rumex pulcher, Rubus sanguineus, Sporobolus (pongens) arenarius, Lythrum plexuosum, and Apium gravealens.

2.2 Emergent vegetation zone

The emergent aquatic plants of this zone grow in depths of water not exceeding 50 cm. The common species are: Phragmites communis, Phragmites communis var.marsillinisis, Arundo donax, Typha angustata, Leersia hexandra, Panicum repens, Cyperus fuscus, Scirpus litoralis, Paspalidium germinatum, Polygonum nodosum, Juncus acutus, Jussiaea repens, Nuphar luteum,and Polypogon sp.

2.3 Aquatic zone

This zone which covers depths of 50 cm to 200 cm has a vegetation consisting of rooted submerged plants, unattached plants and rooted plants with foliage floating on the surface of the water. The species occurring in this zone include: Zanichellia palustris, Potamogeton nodosus, P. lucens, Najas minor, Myriophyllum spicatum, and Ceratophyllum demersum.

3 RELATIVE IMPORTANCE OF THE VEGETATION ZONES

The weeds of the bank zone are the least noxious, and often plants of this zone, such as Lippia nodiflora are useful in consolidating the soil of the banks and preventing erosion. On the other hand, weeds of the emergent vegetation zone and the aquatic zone (submerged vegetation) are the most noxious. The extent of the former zone, however, may be reduced by deepening the ponds so that the shallowest parts will be at least 70 cm. This reduces the area suitable for the plants of the emergent vegetation zone.

4 METHODS OF WEED CONTROL

Three methods of controlling vegetation in ponds are practised in the region and these are briefly described here.

4.1 Mechanical methods and burning

Mechanical means include mowing, slashing, and burning and these were widely used in the past. Owing to an increase in labour costs and a shortage of manpower in recent years, these methods proved to be uneconomical. They also proved to be of low efficiency in keeping the banks clear of vegetation, as mowing and burning have to be repeated several times a year.

4.2 Herbicides

The ready supply of herbicides on the market and the nature of the uncomplicated equipment for their application led to the widespread use of herbicides for controlling pond weeds. There are three main methods employed in the use of herbicides for this purpose, viz. soil sterilization, foliage treatment and application in pond water.

Herbicides are used to reduce the fertility of the soil mainly on the bank zone. Foliage treatment has only negligible effect on the soil and is used mainly in the emergent vegetation zone. For the control of vegetation in the aquatic zone, the herbicide is applied directly to the pond water in which it dissolves. Repeated treatment of some herbicides of this nature such as sodium arsenite, will affect the bottom fauna and indirectly the fish yield.

5 EVALUATION OF HERBICIDAL METHODS

5.1 Soil sterilization

The expense involved in this method makes it impractical for most large ponds. It may, however, be used successfully in small ponds, limited areas of the banks of ponds, or for spot treatment of relatively clean areas. Among the products available C.M.U. preparation is intended for sterilization of areas of mixed vegetation of dicotyledons and monocotyledons, but not for deep rooted perennial plants. Products containing sodium chlorate are suitable for controlling deep-rooted vegetation, such as *Phragmites communis*, *Prosopis furcata* etc. As a result of their high solubility these chemicals rapidly penetrate to a depth which C.M.U. only reaches after a very long time.

5.2 General herbicides

Although most of these do not penetrate the plant material to any great depth, they are effective on contact with the plant tissue. Control of perennials with these general herbicides requires thorough continuing treatment whenever growth occurs. Therefore, their use in ponds is very limited.

5.3 Selective herbicides

These are used in the control of specific plants or groups of plants, leaving others relatively unaffected. The most widely used of these herbicides are: 2,4-D(2,4 dichlorophenoxy acetate) and 2,4,5-T(2,4,5 trichlorophenoxy acetate). The herbicide 2,4-D has a marked selective action on dicotyledonous plants, although in some cases it does affect a number of monocotyledons. This herbicide as a rule penetrates the foliage. The obvious disadvantage of the use of this herbicide is that it will destroy agricultural crops if inadequate precautions are taken in restricting its area of use. Three types of chemical preparation containing 2,4-D are marketed: viz. (a) sodium salts, (b) amine salts, and (c) esters of 2,4-D. The last is used for controlling the dicotyledon *Inula viscosa*, a perennial. Dalapon has proved the most successful herbicide in controlling some of the most noxious weeds in fish ponds, such as Phragmites communis, Typha angustata and Panicum repens.

5.4 Herbicides applied in pond water

The herbicides widely used in the region and the weeds successfully controlled by them are given below:

Herbicide	Weeds controlled
2,4-D	Broad leafed annuals such as Inula viscosa, Prosopis furcata and Myriophyllum spicatum.
2,4-D esters	Typha angustata, Scirpus litoralis, and Cyperus sp.
2,4,5-T	Rubus sp., Conyza dioscoridis, Polygonum sp.
Sodium arsenite	Potamogeton nodosus (4 - 5 ppm in the pond water)
C.M.U.	Najas minor (1 - 2 ppm in the pond water).

6 COMPARISON OF MECHANICAL METHODS AND CHEMICAL METHODS

Before 1957 mechanical methods were the most common means of weed control, involving mainly mowing by the use of manual labour. The number of days for manual weed control per hectare of pond per annum worked out at 30 - 50 days, which was 30 - 50 percent of the total working days involved in fish farming at that time. The introduction of herbicides eventually reduced the time involved in weed control to 5 - 10 days/ha/annum. It was also found that the total cost of herbicidal control, including the cost of herbicide and equipment, was as low as 20 percent that of manual labour. These figures are based on data collected in Israel.

The difference in time and costs involved between manual and chemical control of weeds is illustrated by the following example of the two methods applied successively to a drainage ditch 250 metres long having a total area of 2,500 square metres. The ditch was heavily infested with Phragmites communis (the most dominant species), Cyperus fuscus, Conyza dioscoridis, Inula viscoza, Lythrum flexuosum and Apium graveolens. The ditch was formerly cleared manually twice a year, which required 15 working days per year. Also, every two years the ditch had to be cleared of silt which had accumulated as a result of the weeds slowing down the flow of water. This required an additional four working days per year. This total of 19 working days each year cost Israeli lira (IL) 190 (IL3 = American $1), or IL 0.76 per metre of ditch. Although this method is no longer applied the relative costs in 1965 would be far higher, due to a large increase in labour costs since 1958.

The efficiency criterion was the rate of flow two months after weeding. When the ditch was cleared by manual labour it was found that some plants such as Phragmites started growing almost immediately, resulting in a connected three hectare pond taking 70 hours to drain at a maximum rate without flooding the banks.

The manual method was eventually superceded by chemical control, involving spraying the ditch four times a year, using a tractor to drive the spraying equipment. The herbicides used were Dalapon and 2,4-D esters at the rate of 4.5 kg to 0.5 litres respectively per application. The total cost worked out at IL 0.16 per metre of ditch, which is 21 percent of that by manual methods at IL 0.76 per metre. The draining efficiency of the ditch also increased very considerably. As a result of the rapid flow of water there was no accumulation of silt. Normally, the first year of chemical control is the most expensive, as larger quantities of herbicides are required to cover the overgrown foliage. In subsequent years the costs generally do not exceed 50 percent of those in the first year.

Most of the work involved in fish farming is to be done from mid-March to late November. This period coincides with the intensive growth phase of most weeds. Manual labour required at this time for weed control as in the past, reduces the amount of labour available at an important time in fish farming activities, such as cropping, sampling, etc. Chemical control may be done in part from December to March, and this reduces labour requirements in the summer months.

The difference in cost between mechanical and chemical weed control methods in 1965 is such that it is only practical and economical to apply the latter method. This is also true for other Near East countries where labour costs are lower than in Israel.

7 BIOLOGICAL CONTROL

7.1 Control by fish

Control of weeds by fish is successfully practised in Israel in carp ponds, grey mullet nursery ponds and tilapia breeding ponds. The intensive growth of the submerged weeds Ceratophyllum and Myriophyllum begins in ponds in March. The carp (Cyrpinus carpio) in densities of 2,500 to 3,000 per hectare and above 250 g average weight, will eradicate these weeds by grazing over the bottom of the ponds. If the fish do not attain this density and average weight by this time of the year, the weeds and also algae (Spirogyra sp.) will develop further and may cover a large part of the ponds. Such heavily infested ponds could then be cleared by turning them into storage ponds for carp of average weight of 5,000 g or above, in densities of 8,000 per hectare. This methods would clear the ponds completely of weeds within 20 days.

The catching season for Mugil cephalus and M. capito fry in Israel is from October to January. The fry are caught at a length of 20 mm and kept in nursing ponds at densities of 100,000 to 200,000 per hectare until April, when they are transferred to rearing ponds as supplementary fish to carp. At this time the fry reach lengths of 4 to 8 cm. A dense filamentous algal growth develops in the nursery ponds during March and April, which causes great difficulties and many losses when catching the mullet fingerlings. The growth of algae may be prevented by stocking the ponds with carps of 500 - 600 g weight at a density of 250 - 300 per hectare. The carp keeps the water turbid, and thus prevents the growth of algae. To avoid wild spawning of the carp in mullet ponds, only male carp is used.

The breeding season of Tilapia sp. in Israel is from April to October. The clear water in Tilapia breeding ponds allows the growth of submerged weeds such as Potamogeton, Myriophyllum and Ceratophyllum, which makes the catching of fingerlings in these ponds very difficult. The same control measures as described for mullet nursery ponds have been found to be efficient in Tilapia breeding ponds also.

7.2 Control by grazing

7.2.1 Cattle

The control of weeds on the bank and emergent vegetation zones by cattle is efficient only for a short time. The cattle only graze on specific weeds such as Phragmites communis and Panicum repens, and do not touch others such as Inula viscosa and Typha augustata. As a result of this preferential grazing, the species composition of the weeds changes within a few years, pond banks which were infested mainly with Phragmites becoming covered with only Inula and Typha.

7.2.2 Nutria (Mycocaster coypus)

This fur-bearing animal was introduced in fish ponds for the dual purpose of producing furs and meat, and clearing the ponds of weeds. Experiments conducted in 1957 showed that nutria is efficient in controlling Typha angustata, Phragmites communis and Polygonum sp. The animal, however, does not eat Inula viscosa, Juncus bufonius and Apium graveolens.

It is necessary to fence the ponds to protect the nutria from wild animals such as the jackal (Vulpes vulpes), the fox (Canis aurens), the otter (Lutra lutra), etc.,and also to prevent the nutria from escaping. The economic feasibility of fencing the ponds depends on the prices fetched by nutria fur. These prices are low on the world market at present,and therefore the culture of this animal is not widespread despite their efficiency in controlling weeds.

7.2.3 Plants

The planting of kikyu grass (Prisatum sp.) along the banks, above the water level of newly built ponds creates a dense cover, which prevents the colonization of weeds or cuttings in the bank zone. The planting of this grass should be done immediately after filling the ponds with water.

8 DISCUSSION

All the methods of weed control described are in current practice in Israel, but manual methods are now rapidly falling into disuse.

The use of herbicides in weed control has become the most commonly used method since 1957, when it was found that chemical control resulted in a saving of 80 percent of the cost of manual control.

There are some disadvantages, however, in the use of herbicides in chemical control methods. An important one is the hazard of accumulation of the herbicides in the bottom of ponds, which ultimately affects total fish production. An example is the harmful effect of sodium arsenite on the bottom fauna, which is important in the food chain in ponds. There are also serious side effects in the use of herbicides, which although not affecting the fish population in any way, have to be taken into consideration. It has been shown that fertility of water fowl is reduced after feeding on embankment grasses treated with Dalapon. Further, as described earlier in the text, some herbicides, such as 2,4-D and 2,4,5-T will destroy neighbouring crops if inadequate precautions are taken in restricting their area of use.

The recurring cost of chemical control increases the eventual cost of fish production, but biological methods, once operative, are more or less self-maintaining, and also increases the profitability of ponds by adding to the total production in the form of additional fish or other by-products, such as nutria. Animals used in biological control may also utilize areas other than ponds in a fish farm, such as ditches, embankments and other normally unproductive areas. It would therefore appear advisable to concentrate future research on biological methods in weed control.

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PRESENT TRENDS IN THE CONTROL OF WEEDS IN FISH CULTURAL WATERS OF ASIA AND THE FAR EAST

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PRESENT TRENDS IN THE CONTROL OF WEEDS IN FISH CULTURAL WATERS OF ASIA AND THE FAR EAST

Abstract

Noxious floating, submerged, emergent and marginal aquatic weeds and filamentous and bloom-forming algae cause extensive damage to inland fisheries of the tropical and sub-tropical countries of Asia and the Far East. Weed problem is less acute in China, Taiwan and Japan.

Manual and management methods are still practised in most countries of the region for control of weeds in small water bodies. Owing to their high costs or unsuitability, mechanical methods have been rarely used in fishery waters. None of the herbicides, except 2,4-D, are extensively used, for similar reasons. Dalapon and possibly ammonia and Diquat are herbicides of promise recently tried against specific weeds. Algal blooms have been controlled only by shading or with copper sulphate. Control of underwater vegetation using herbivorous fishes is currently receiving wide attention because of its manifold advantages over other methods. For more efficient clearance at low costs, combination of methods have been preferred to single methods.

Interest has revived in the possible utilization of cleared weeds as composts, fodder or for other purposes.

The urgent need for further knowledge on noxious weeds and for standardization of techniques of well-tried and economical control methods for their effective use against specific weeds is emphasized.

TENDANCES ACTUELLES EN MATIERE DE LUTTE CONTRE LA VEGETATION ENVAHISSANTE DANS LES EAUX PISCICOLES D'ASIE ET D'EXTREME-ORIENT

Résumé

Dans les régions tropicales et sub-tropicales de l'Asie et de l'Extrême-Orient, d'importants dégâts sont causés aux pêcheries intérieures par l'envahissement de plantes aquatiques flottantes, immergées, émergées et marginales et par la prolifération d'algues filamenteuses et buissonnantes. Le problème de la végétation aquatique est moins aigu en Chine, à Taïwan et au Japon.

Dans la plupart des pays de la région, la lutte contre les plantes aquatiques dans les plans d'eau de faible superficie, s'effectue encore par des méthodes manuelles et culturales. Les méthodes mécaniques ne sont guère répandues, soit parce qu'elles coûtent cher, soit parce qu'elles ne conviennent pas aux conditions d'exploitation. Pour les mêmes raisons, aucun des herbicides, à l'exception de 2,4-D, n'est couramment employé. Parmi les herbicides qui ont donné de bons résultats contre des plantes spécifiques au cours d'expériences récentes, on trouve le Dalapon et éventuellement l'ammoniaque et le Diquat . Les proliférations d'algues n'ont pu être maîtrisées qu'en empêchant la pénétration de la lumière ou en déversant dans l'eau du sulfate de cuivre. La destruction de la végétation immergée à l'aide de poissons herbivores suscite actuellement un vif intérêt en raison des nombreux avantages que comporte cette solution. Pour obtenir à moindres frais les résultats les plus efficaces, on a donné la préférence à des méthodes mixtes plutôt qu'à un procédé unique.

On s'intéresse de nouveau à la possibilité d'utiliser les produits de faucardage en tant que composts, fourrage ou à d'autres fins.

L'auteur souligne qu'il est urgent de poursuivre les travaux de recherche sur les plantes nuisibles et de mettre au point des techniques standard, bien éprouvées et économiques de lutte contre certaines plantes déterminées.

TENDENCIAS ACTUALES EN LA LUCHA CONTRA LAS MALAS HIERBAS EN LAS AGUAS PISCICULTURALES DE ASIA Y EL LEJANO ORIENTE

Extracto

Las hierbas acuáticas nocivas flotantes, sumergidas, emergentes y marginales, así como las algas flamentosas y que forman floraciones, causan mucho daño a las pesquerías interiores de los países tropicales y subtropicales de Asia y el Lejano Oriente. Los problemas causados por tales hierbas nocivas son menos intensos en China, Taiwán y Japón.

En la mayoría de los países de la región se practican todavía métodos manuales y culturales para luchar contra las malas hierbas en las pequeñas masas de agua. A causa de su elevado costo e impracticabilidad, los métodos mecánicos rara vez se han usado en las aguas de pesca. Por razones análogas, tampoco se utiliza ampliamente ninguno de los herbicidas salvo 2,4-D. Dalapon y, posiblemente, amoníaco y Diquat son herbicidas prometedores que se han ensayado recientemente contra ciertas hierbas adventicias. Se ha luchado contra las floraciones de algas solamente impidiendo el paso de la luz o mediante sulfato de cobre. La lucha contra la vegetación subacuática utilizando peces herbívoros está mereciendo actualmente amplia atención a sus múltiples ventajas respecto a otros métodos. Para una eliminación más eficaz a poco precio, se han preferido métodos mixtos a métodos únicos.

Se ha reavivado el interés por la posible utilización como abonos, forraje o para otros fines, de las algas extirpadas.

Se hace resaltar la apremiante necesidad de contar con mayores conocimientos sobre las malas hierbas y para la uniformación de los métodos de lucha contra ellas bien ensayados y económicos, para su empleo eficaz contra determinadas clases de hierbas adventicias.

1 INTRODUCTION

One of the major problems facing pisciculturists of some of the countries of Asia and the Far East has been the excessive growth of leafy aquatic weeds in ponds, which makes exploitation of these waters difficult. It is well known that though small numbers of certain plants are frequently desirable or even necessary, excessive growth of weeds reduces productivity by the depletion of valuable nutrients or by shading, by restricting living space for fish, impeding oxygen circulation and helping in the gradual silting up of water bodies. They also interfere with fishing operations and serve as ideal haunts for predatory and weed fishes, and harmful molluscs and insects. Though decomposition of soft submerged plants could increase the nutrients, hard plants with not easily soluble remains make the water body more unproductive. Undue development of noxious algae is also harmful since they prevent the growth of more useful organisms and often cause fish mortality either by oxygen depletion or liberation of toxic substances during their decomposition.

Thus, a certain degree of control, or, in some instances total eradication is necessary for successful fish culture. The chief aim of this paper is to assess the nature and extent of the problem in Asia and the Far East, including Australia and New Zealand and to review the progress made in the control or eradication of noxious weeds in the region.

The author wishes to express his gratitude to a number of scientific workers in the region, especially in Australia, New Zealand, Malaysia, the Philippines, Taiwan, Japan and the FAO regional office at Bangkok for their cooperation in collecting information on the subject from their respective countries or regions.

2 CLASSIFICATION OF AQUATIC WEEDS

Weeds which are a nuisance in fishery waters belong to various families of dicots, monocots, filamentous and bloom-forming algae and rarely to water ferns.

From the point of view of weed control it is more convenient to classify them according to their habits and habitat. Thus, some fishery biologists (Lawrence, 1955) frequently divide them into: (i) floating weeds which are unattached and free-floating with their leaves above the water surface and roots within water (e.g. Eichhornia, Pistia, Azolla); (ii) emergent weeds which are rooted in the bottom soil but have all or some of their leaves, leaf lamina or shoots above the water surface (e.g. Nymphaea, Trapa, Myriophyllum); (iii) submerged weeds which are completely submersed within water but may be rooted in the bottom soil (e.g. Hydrilla, Najas, etc.) or free-floating (e.g. Ceratophyllum and Utricularia); (iv) marginal weeds which fringe the shore line of the water body and are mostly rooted in water-logged soil (e.g. Typha, Phragmites, etc.); (v) filamentous algae which form "mats" in the marginal area or "scums" in the main body of water (e.g. Spirogyra, Pithophora, etc.); and (vi) algal blooms occurring dispersed in the water body (e.g. Microcystis, Anabaena, etc.). Pruginin and Lipshitz (1957) distinguish weeds of fish ponds into three categories, viz., (i) weeds of belt-1, which are marginal plants found in the dry embankments of the pond, (ii) weeds of belt-2 which are weeds in shallow water and (iii) weeds of belt-3 which are true aquatics and are either emergent or submerged.

Hickling (1962) states that it is usual to divide water plants into two kinds, hard and soft plants, the former mostly reeds, rushes and sedges and the latter chiefly genuine underwater aquatics. Aquatic plants can also be classified into broad-leafed and narrow-leafed ones, the latter mostly grasses, sedges and rushes.

Whatever be the classification, the control measures adopted often depend on the particular category of plants to be controlled.

3 COMMON AQUATIC WEEDS AND THE EXTENT OF WEED PROBLEM IN COUNTRIES OF THE REGION

Generally speaking, the problem of weeds in fishery waters is more acute in the tropical and sub-tropical countries of the region, particularly in India, Pakistan, Burma, Ceylon, Malaysia, Indonesia and to a lesser extent in Thailand, Vietnam, Cambodia, Laos and the Philippines. In China, Taiwan and Japan it is not so acute due to the temperate climate and other factors. In Australia and New Zealand, the weed infestation is mainly in irrigation channels and drains and occasionally in lakes and reservoirs. The common weeds and the extent of the problem in different countries and the causes of weed infestation as could be assessed from available sources are described below.

3.1 Common weeds and the extent of infestation

India and Pakistan

As in many other countries, the water hyacinth is one of the most noxious of the floating weeds. Introduced in Bengal at the turn of the present century, probably from Ceylon, it has spread to almost all parts of the sub-continent, Burma and Malaysia, especially in the coastal districts causing considerable damage to fisheries. Vaas (1951) refers to damage caused to the Bengal fisheries to the tune of 45 million kg of fish a year by the overgrowth of the weed in 150,000 hectares of water area. The phenomenal spread of the plant, which can increase in volume by about 700 percent within fifty days (Parija, 1934) or from a pair of plants to 1200 in four months (see Poling and Barr, 1965) could be gathered from the fact that in Bengal alone an estimated 25,900 sq. kilometers of water area was infested by the weed in 1945, compared to 10,360 sq. kilometers in 1930. Because of the various control and reclamation measures adopted ever since, the weed has been well contained by 1965. Though not as noxious as water hyacinth, two other weeds, *Pistia stratiotes* and *Salvinia* sp. are also troublesome in coastal areas. Recently, there has been an alarming increase in the latter weed, particularly in Kerala. Other floating weeds causing minor problems are *Azolla pinnata*, *Spirodela* and *Hygrorhiza*.

Next to water hyacinth, the submerged weeds *Hydrilla verticillata* and *Najas* spp. are the most noxious, especially in N.E. India. Others which could be harmful are *Vallisneria spiralis*, *Nechamandra* (*Lagarosiphon*) *alternifolia*, *Ottelia alismoides*, *Potamogeton pectinatus*, *Ceratophyllum demersum*, *Utricularia* and *Chara* spp., the emergent weeds *Nymphaea* spp., *Nelumbo nucifera*, *Nymphoides* (*Limnanthemum*) spp., *Trapa* and *Myriophyllum* spp., and marginal weeds like *Typha* spp., *Phragmites karka*, *Panicum repens*, *Scirpus*, *Juncus*, *Cyperus* and *Eleocharis* spp., *Monochoria* spp., *Colocasia antiquorum*, *Sagittaria sagittifolia*, *Limnophyton obtusifolium*, *Hydrolea zeylanica*, *Limnophila* spp., *Ipomoea aquatica* and *Jussiaea repens* (Biswas and Calder, 1937; Philipose *et al*., 1962). The filamentous algae *Spirogyra* and *Pithophora* and more frequently a number of planktonic algae like *Microcystis* and *Anabaena* are a source of nuisance in waters free of higher aquatic plants.

According to a recent estimate (Mitra, 1964), about 680,000 hectares of water area mostly in the form of ponds, tanks, reservoirs and artificial lakes are available for fish culture in various States of India of which a third is in West Bengal. Since the States of Andhra Pradesh, Assam, Madhya Pradesh and Madras are not included in this estimate, the total cultivable waters may be taken roughly as 800,000 hectares. Though no exact estimate of weed infestation in these areas is available, the eastern zone comprising West Bengal, Bihar, Orissa, Assam and Manipur (from various sources; also see Philipose *et al*.,1962) appears to have the maximum incidence of 40-70 percent compared to 20-50 percent for the rest of India. Assuming that the average incidence is only about 40 percent, about 320,000 hectares of water area have to be cleared of weeds annually for the culture of fish.

East Pakistan has weed problems more or less similar to those of West Bengal (see Ahmad, 1953 and 1954). In W. Pakistan, water areas available for fish culture appear to be mostly in the form of reservoirs and the weed problem does not appear to be as acute there as in E. Pakistan.

Burma

Apart from the water hyacinth, which is a problem in some areas (Tin *et al.*, 1949), some of the common water weeds are *Nelumbo nucifera*, *Ipomoea aquatica*, *Herpestis monnieria*, *Limnanthemum parviflorum*, *Limnophila* spp., *Utricularia racemosa*, *Enhydra fluctuans*, *Najas minor*, *Alisma plantago*, *Sagittaria guayanensis*, *S. sagittifolia*, *Typha elephantina*, *Nipa fruticans* (in salt marshes), *Leersia hexandra*, *Hygrorhiza aristata*, *Cyperus cephalotes*, *Eleocharis* spp., the duck weeds, *Salvinia* spp. and *Azolla pinnata* (see Biswas and Calder, 1937). However, the extent of damage caused to fisheries is not known.

Ceylon

In Ceylon considerable areas are available for fish culture, mostly in the form of large tanks and small lakes. The flora is somewhat similar to that of India (see Biswas and Calder, 1937; Dassanayake and Chow, 1954). The chief weeds are *Eichhornia*, *Pistia*, *Salvinia*, *Hygrorhiza*, *Aeschynomene*, *Neptunia*, *Nymphoides*, *Limnophila*, *Jussiaea*, *Hydrolea*, *Monochoria*, *Colocasia*, *Alternanthera*, *Scirpus*, *Eleocharis*, *Panicum* and *Leersia*. *Microcystis* forms blooms in a number of tanks and lakes.

Malaysia

Malayan ponds, particularly those in Malacca, are relatively infertile and the weeds usually met with are the submerged *Enhydra angustipetala* and *Chara flexilis*, and sedges and rushes like *Fimbristylis acuminata* and *Isachne globosa* (Hickling, 1962). A few other plants which at times occur luxuriantly are *Nymphaea* spp., *Sagittaria guayanensis*, *Limnophila villosa*, *Utricularia* spp. and *Najas graminea* (Prowse, 1960). There is also the water hyacinth, but it has not been considered a problem at present on account of its usefulness as pig fodder.

Indonesia

Water hyacinth (Vaas, 1951) is the most noxious, though other weeds characteristic of the tropical belt including *Hydrilla*, *Ceratophyllum*, *Ipomoea*, *Potamogeton*, *Salvinia* and *Azolla*, various emergent plants, marginal grasses, sedges and rushes grow luxuriantly (Vaas, *loc. cit.*; Vaas and Schuurman,1949; Ling, 1960) causing a lot of damage to fisheries. In brackish-water ponds, *Najas*, *Ruppia* and filamentous algae are frequently found (Hora and Pillay, 1962).

Viet-Nam, Cambodia and Laos

As in other South East Asian countries, the water hyacinth (see Vaas, 1951) and various other weeds occur, mostly in lakes, but no detailed information is available.

Hong Kong and Korea

Because of the few inland waters and the climate, weeds are not a problem in these countries.

Taiwan and China

In the mainland of China and in Taiwan, weeds of inland waters are mostly the water hyacinth, *Pistia stratiotes*, *Salvinia natans*, *Azolla* sp., the duck weeds and *Ipomoea reptans*; *Potamogeton* spp., *Vallisneria spiralis*, *Hydrilla verticillata*, *Najas minor*, *Ceratophyllum demersum*, *Anacharis* sp., *Myriophyllum verticillatum* and *Chara* spp. and *Typha latifolia* and *Scirpus* sp. However, these weeds do not cause any serious problems in pond management (Lin, personal communication).

The Philippines

The aquatic weed problem in the Philippines is mostly due to emergent rooted vegetation, especially grasses, floating weeds such as water hyacinth and duck weeds and seasonal blooms of *Microcystis*, which occur in fish ponds or low-lying paddy fields (Rabanal, personal communication, 1956). According to Vega,(1954; and personal communication, 1965), the weeds commonly found in fish ponds are *Ottelia alismoides*, *Hydrilla verticillata*, *Vallisneria gigantea*, *Sesbania cannabina*, *Sagittaria sagittifolia* and *Ceratopteris siliquosa*, whereas in low-land paddy fields and canals, various species of *Cyperus* and *Scirpus*, *Eleocharis equisetina*, various grasses (including *Echinochloa crusgalli*) and Compositae, *Hydrolea zeylanica*, *Nasturtium indicum* and several other weeds also occur.

Japan

In fishery waters of Japan (Kuronuma and Nakamura, 1958), the most common weeds are *Myriophyllum spicatum*, *Ceratophyllum demersum*, *Potamogeton* spp., *Hydrilla verticillata*, *Trapa* sp., *Phragmites communis*, *Scirpus maritimus* and *Zizania latifolia*, but these do not cause any difficult problem, particularly because most of them are controlled by the grass carp.

Australia

In confined waters, mostly reservoirs in Australia, the main difficulty has been from algal blooms. Water hyacinth, originally introduced towards the end of the last century (see Meadley, 1954) spread in creeks and lagoons of New South Wales and S. Australia and in Lake Monger of W. Australia, but timely action has either eradicated it or checked its spread.

At present aquatic weeds are a problem only in irrigation and drainage systems (Dunk, 1953; 1954a; 1955; Bill, 1963a). Since the weeds infesting these systems and the control methods adopted are in some respects similar to those of fishery waters, they are referred to briefly here. The most troublesome weeds are *Typha angustifolia*, *Phragmites communis*, *Paspalum distichum*, *Cotula coronopifolia*, *Juncus articulatus*, *Eleocharis acuta*, *Myriophyllum propinquum*, *M. elatinoides*, *Vallisneria spiralis*, *Potamogeton tricarinatus*, *P. ochreatus*, the red *Azolla*, *A. filiculoides* and some willows (*Salix*).

New Zealand

In New Zealand (see Walker, 1954; Mathews, 1960; Mason, 1960 and 1964), the water hyacinth, *Azolla rubra*, *Lemna minor*, *Wolffia arrhiza*, *Rorippa* (*Nasturtium*) spp., *Ceratophyllum demersum*, *Ottelia ovalifolia*, *Elodea* (*Anacharis*) *canadensis*, *Egeria densa*, *Lagarosiphon major*, *Aponogeton distachyus*, *Potamogeton* and *Myriophyllum* spp., *Calitriche* sp., *Typha* spp., *Alisma plantago-aquatica*, *Glyceria* sp. and *Paspalum*, *Juncus*, *Scirpus*, *Eleocharis* and *Ludwigia* spp. are the most common in ponds and lakes. Water hyacinth has become more or less naturalized in the northern island. Mason (1960) states that some of the submerged weeds originally collected as aquarium plants got a stronghold in lakes and ponds later. In her opinion (personal communication, 1965) some of these weeds could cause trouble in ponds should they be used for the cultivation of fish.

Guam and Hawaii

According to Vernon E. Brock (personal communication, 1956), *Potamogeton crispus* and *Utricularia* sp. are the only weeds of any consequence in the Fena Reservoir in Guam. In Hawaii proper, weeds occur in irrigation systems of sugar plantations.

3.2 Causes of weed infestation

A number of factors, jointly or severally, are responsible for the type of weeds and the extent of infestation in cultivable waters of the region. Some of these are the geographical and climatic conditions; topography, depth, extent of silting up and the inherent or induced fertility of the water bodies; clarity of water; connection with sources of infestation, floods and currents; animal and human agencies which bring weeds or their reproductory parts, the latter often inadvertently, from outside sources; multiple ownership or lack of proper ownership of cultivable waters, scarcity and high cost of labour or sometimes lack of proper incentive or funds to clear weeds, all of which result in neglect, improper utilization or improper year-round maintenance.

The greater incidence of aquatic weeds in the tropical and sub-tropical belts of the region is no doubt due to geographic and climatic conditions, though there are other contributory factors as well. Thus, although man has apparently to be blamed for the introduction and spread of the water hyacinth in Asia and the Far East (and some other regions), its failure to spread to the northern temperate region has been due to its extreme susceptibility to frost.

Though seasonal blooms of algae in fish ponds may be due to the natural fertility of the ponds or periodical manuring, temperature, sunlight and other factors, the persistence of certain blue-green algal blooms is variously attributed to their ability to store certain nutrients for use when they are in short supply or to produce and liberate certain metabolites which help in the exclusion of other algae.

4 METHODS OF CONTROL

Common methods employed in the control or eradication of aquatic weeds fall into four major categories, viz., manual and management, mechanical, chemical and biological. Sometimes, one or more of these methods are combined for better efficiency, economy or other reasons.

4.1 Manual and management methods

Management methods are mainly preventive measures whereas in manual methods human labour is employed with or without the aid of simple implements. Before the advent of mechanical, chemical and biological control methods, manual and management methods alone were employed. Even now, with perhaps the exception of Japan and Australia, where labour is very expensive, most of the countries in the region employ manual labour to a great extent and they might continue to do so for a long time. Only when they are ineffective, other methods are resorted to.

In India (see Philipose, 1957 and 1963; Hingorani, 1964) traditional methods of hand picking, uprooting and cutting of emergent and marginal weeds with the aid of simple implements like hand scythes or netting of some floating weeds with wire, coir or cloth nets are convenient and cheap for small bodies of water. For the more noxious rooted submerged weeds, log weeders with spikes and barbed wire, hand drawn bottom rakes, bamboo poles with basal cross attachment or broom forks with toothed prongs both of which are rotated to uproot weeds, and long-handled forks and sickles used for raking or cutting are often successfully used. Frequent cutting of the leaves of water lilies as practised in western countries (see Swingle and Smith, 1950) has also proved useful and economical. Water hyacinth masses occurring in some inland waters are also pushed out through outlets into rivers during floods employing manual labour.

In Thailand floating weeds are cut up into convenient patches and either pushed down flooded channels into rivers or dragged into shallow areas and subsequently removed manually or burnt after drying. In Vietnam and Cambodia also (see Philipose, 1957) weeds are cleared either by manual labour or by natural agencies like floods. In Malaysia (Hickling, 1962) a certain amount of manual labour is used for cutting grasses and sedges occuring in fish ponds. Dassanayake and Chow (1954) state that owing to the high cost of manual clearance of weeds like Pistia from Ceylonese waters, chemical methods are replacing it.

In Japan (Kuronuma, personal communication, 1956; Kuronuma and Nakamura, 1958), the prevailing high cost of manual labour permits its use only on a limited scale. In Australia also (Dunk, 1954b) manual labour is used only for cutting and shovelling infestations of weeds like Typha or as supplementary to mechanical and chemical methods.

Management methods like deepening of marginal shelves to prevent the growth of marginal weeds, burning, grazing or ploughing-in of marginal grasses, draining and desilting and erecting barriers to exclude floating weeds like water hyacinth are practised in varying degrees in all the countries of the region, though not systematically. Since most of the farms are still not planned ones, flooding by artificial regulation of water is not yet possible, the only control of rooted weeds that takes place being during sudden natural floods. Narayanayya (1928) found artificial creation of turbidity with silt in flowing waters of Deccan useful for controlling submerged weeds. According to Alikunhi (1956) raw cow dung applied as a liquid spray on the water surface in nursery ponds gives temporary control of algal blooms by shading.

4.2 Mechanical methods

In the Asian and Far Eastern region, mechanical methods have been used only on a limited scale for the clearance of weeds from fishery waters. However, in irrigation channels and drains of Australia, a number of mechanical devices like drag-line excavators, weed bucket attachments, Chinese rake, weed hook, rotary hoe, Walsh broad arrow cutter, submarine saws, underwater mowers and drag chains and scythes have been used quite frequently. These are generally operated from the bank of a canal or drain by a horse team or tractors (Dunk, 1954b). In rivers, weed launches are also used (Rogerson, 1953).

In the Philippines (Rabanal, personal communication, 1956) isolated trials of mechanical removal of weed from limited areas of usually less than one hectare have been made by some private fish pond operators.

In the Tropical Fish Culture Institute at Malacca, Fimbristylis and Isachne were effectively controlled (Hickling, 1962) by cutting with an Allen motor grass cutter provided with an extension piece and mounted on two 45-gallon (204.6 l) oil drums, after filling the pond with water up to about 90 cm. Three or four subsequent cuttings of the feeble growth of weeds employing manual labour only gave complete eradication of the weeds.

In India also, isolated trials have been made by private fish farmers of Bengal and Assam. In Bengal a weed launch with long sickles mounted at the bow in the form of a V and having reciprocal action has been used for cutting weeds like Colocasia, Cyperus and other tall weeds in shallow waters and in Assam thick infestations of water hyacinth have been dragged to the margin by power winches or cleared by mechanical lifts.

More recently, the Fisheries Department of the State Government of Orissa have been using diesel-operated winches for the clearance of thick infestations of rooted submerged aquatics (see also Philipose, 1963).

Generally speaking, mechanical methods are slow, quite expensive and beyond the means of the average fish farmer in the region. Follow-up operations employing manual labour is invariably essential and the duration of benefits obtained is also short. The difficulty of transporting and installing heavy equipments in scattered low lying ponds without firm embankments make them unsuitable for such waters (FAO/UN, 1954).

4.3 Chemical control

Though isolated trials for the control of aquatic weeds using poisonous chemicals were made in the region as early as 1920, interest in the use of herbicides was stimulated only after the availability of the newly discovered hormone weedicides late in the nineteen forties. Herbicides have now become popular in a number of South East Asian countries and in Australia and New Zealand, though it cannot be stated that they are extensively used.

The more important weedicides used against leafy aquatic weeds in these countries are arsenicals like arsenious oxide, sodium arsenite and "Mercene Special"; boron compounds like borates and borax, alone or mixed with chlorates (e.g. polychlor-borate); bromides like dibromide-20 (sold as "Diquat"); chlorates of sodium ("Atlacide"); chlorinated hydrocarbons (also known as aromatic solvents) like mono- and dichlorobenzene and coal tar naphthas; copper salts like copper sulphate; diesel oils and power kerosene (H.S.D. and "Powerine"); 2,2-dichloropropionic acid ("Dalapon", "Dowpon", "Tafapon", etc.); nitrogenous and phosphate fertilizers like ammonia, urea and superphosphate in high concentrations as weedicides; phenoxy-compounds (also known as hormone weedicides) like 2 Methyl 4-Chloro-Phenoxy Acetic acid (M.C.P.A. sold as "Methoxone", "Agroxone", "Phenoxylene-30", etc.), 2,4-Dichlorophenoxy acetic acid (2,4-D sodium salts sold as "Fernoxone", "Chloroxone", "Taficide-80", "Cidico", etc. or amine salts like "Shell Weed Killer-D", "Weedar-77", etc., or ethyl esters like "Dicotox", "Weedone-57", etc.) and 2,4,5-Trichlorophenoxy acetic acid (2,4,5-T); substituted phenyl ureas like C.M.U.; sulphamates and thiocyanates of ammonia; triazine compounds like "Simazine"; and trichloro-acetic acid (T.C.A.). Granulated or pelleted preparations of 2,4-D, Dalapon and C.M.U. have also been used occasionally (also see Dunk, 1957; Lawrence, 1962).

These weedicides show a wide range in chemical structure and their killing action is either by direct contact resulting in the destruction of protoplasm including chlorophyll or by translocation from the treated part of the plant to other parts, the killing action being a delayed one. They are applied on the foliage, in the water in which the weeds grow or in the soil where the roots penetrate. Some of them show selective action against specific weeds or particular classes of weeds, whereas others affect almost all plants equally and are non-selective. Non-selective weedicides or mixtures of several weedicides are preferable for use in fishery waters unlike in crop fields where the weeds occurring among useful crops have to be controlled without damaging the latter.

Copper sulphate has been the only algicide commonly used in the region and that too in some types of waters only.

How these herbicides have been used against specific weeds in Asia and the Far East and their relative suitability and economics are discussed below.

4.3.1 Floating weeds

4.3.1.1 Eichhornia crassipes (water hyacinth)

Early experiments in the eradication of water hyacinth with formalin, steam, etc. (Bose, 1923), were mainly exploratory and the use of arsenious oxide (McLean, 1922) and copper sulphate (Parija, 1934) were abandoned either due to their poisonous properties or the incomplete kill obtained. With the possible exception of trials by Chaudhuri (1956) with "Mercene Special" in which he reported good results, work done in the region since 1947 on water hyacinth has been with hormone weedicides. M.C.P.A. (Kar, 1947; Mitra, 1948; Padwick, 1948; Thomas and Srinivasan, 1949; Tin et al., 1949; Joshi et al., 1950) and 2,4-D (Joshi et al., 1950; Ocfemia and Javier, 1950; Derico, 1951; Vaas, 1951; Meadley, 1954; FAO/UN, 1954; Saha et al., 1958; Bhinyoying, 1959; Singh, 1962 and Ramachandran, 1963b) have been widely used in the region for small or fairly large-scale eradication of the weed. Of these, the studies of Vaas in Indonesia have been quite exhaustive, including its effect on fish and their biota. Tin et al. (1949) studied mainly the biological effects of the weedicide. Meadley obtained complete eradication of a 6.6 hectare infestation in Lake Monger, W. Australia, with a low volume spray of 2,4-D after finding chlorinated benzenes ineffective. The usual rate of application of 2,4-D against this weed is 4.5 - 6.7 kilograms per hectare in suitable carriers and proper dilutions, but sometimes higher rates or a second spray may be necessary.

Thus, work done in the region and experiences from other continents conclusively prove that 2,4-D is one of the most effective answers for water hyacinth without harmful effects on the fishery, spraying personnel and stock, and at reasonable costs. However, the results obtained and the costs have not always been uniform for various reasons to be discussed later.

4.3.1.2 Pistia stratiotes and Salvinia spp.

Parija (1934) reported effective kill of these plants with glossy or hairy leaves by kerosene sprayed at about 1,100 litres per hectare. Even better results were obtained when a 0.06 percent solution of copper sulphate was added to the kerosene. Methoxone (Kar, 1947; Thomas and Srinivasan, 1949) has also been successfully used against these weeds, 0.56 kg/hectare of the weedicide being effective if the weeds are properly wetted (Padwick, 1948). Dassanayake et al. (1954) found Phenoxylene-30 and 2,4-D amine salt quite effective and cheap for controlling Pistia in Ceylon. A co-solvent or wetting agent like "Teepol" added in sufficient quantity to the M.C.P.A. improved the results. Addition of kerosene or diesel oil and a little emulsifier to the water used quickened the action. For Salvinia, only the amine salt used along with mineral oil gave good results. "Shell Salvinia Weed Killer", specially prepared by Shell agents for use in Ceylon is reported (see Ling, 1960) to have killed fish within six hours of spraying.

In yard trials in India (see Barrackpore, 1958 - Annual Report for 1957-58) complete kill of the plants was obtained with H.S.D. and Powerine at 775-1,100 litres per hectare during bright weather. Field trials were not carried out owing to the high costs involved.

4.3.1.3 Azolla filiculoides

In Australian irrigation systems (Dunk, 1954a; 1955) this plant has been controlled by diesel distillate sprayed at 550-1,100 litres per hectare.

4.3.2 Marginal weeds

Much of the work on control of marginal weeds with herbicides reported from the region has been carried out in irrigation and drainage systems or low-lying paddy fields. In Australian irrigation systems, marginal and ditch bank weeds like Juncus, Cotula, Paspalum, Phragmites and Typha have been controlled (Dunk, 1953; 1954a; 1955) either by the soil sterilants T.C.A., Atlacide, polychlor-borate, ammonium sulphate, C.M.U. and sodium 2,4-D or by foliage sprays of amine salts or oil-based esters of 2,4-D and 2,4,5-T. The soil sterilants proved costly on account of the high rates of application required and even in the most effective ones like C.M.U. and 2,4-D, the control lasted only for a season. Sprays of the 2,4-D amines and esters ranging from 3.4 - 13.5 kilograms acid equivalent per hectare proved quite effective at comparatively low costs. 2,4,5-T was useful against woody plants including Salix. Dalapon (Dunk, 1957; Bill, 1963a) and amitrole (3, amine-1,2-4-triazole) alone or mixed with ammonium thiocyanate (Bill, 1963b) are also currently used against marginal grasses and reeds and are proving useful.

In the Philippines, a number of plants of low-land paddy fields have been controlled by 2,4-D, but the water grass Echinochloa crusgalli which was hardest to control (Vega, 1954) had to be treated in the seed or seedling stage. Hickling (1962) reports that Dowpon did not prove useful against marginal weeds at the Malacca Fish Farm because of their quick regeneration. Wills (1960), from his experience in New Zealand, states that when Dalapon by itself is not effective, a mixture of Dalapon and Amitrole or of Dalapon, Amitrole and 2,4-D gives better results. In India, small-scale treatments of marginal grasses, sedges and rushes (also Pistia and Nymphoides) with Taficide-80 or tafapon mixed with small quantities of Surf or calcium chloride have given fairly good results (Ramachandran and Prabhu, personal communication).

Thus, 2,4-D sodium or amine salts and esters and Dalapon have proved useful in varying degrees against a number of grasses, sedges, rushes and reeds. However, the costs are high in most instances. Necessary precautions for saving adjacent crops and orchards are necessary when using the highly volatile esters.

4.3.3 Emergent weeds

Herbicides have been used against this class of weeds only rarely in Asia and the Far East, probably because they have not been considered as noxious as the other classes of weeds or because alternative cheaper methods are available for their control. In India, good results have been reported in the control of Nymphaea with Dicotox (Srinivasan and Chacko, 1952) and of Nelumbo and Euryale with Taficide-80 (Singh, 1962). Mitra and Banerjee (1966) recently obtained a certain measure of success in eradicating Nymphoides, Nymphaea and a few other rooted aquatics, including Hydrilla, by applying copper sulphate pelleted with mud on the bottom soil in four to five intermittent doses totalling 175-180 kg per hectare without killing fish in the water body.

In Australia, emergent forms of Myriophyllum have been controlled easily by the application of 1.12-2.24 kg of 2,4-D acid equivalent per hectare, all formulations, viz., esters, amines and sodium salts being effective.

4.3.4 Submerged weeds

A number of chemicals have been used against this class of weeds. In India, copper sulphate has been used alone or in combination with ammonium sulphate (Chattopadhyay, 1951) for the control of Chara or after a pretreatment with sulphuric acid (Banerjea and Mitra, 1954) for the control of Ottelia and other submerged weeds in alkaline fish ponds. In the latter instance fish were killed at the concentration of 10 ppm of the chemical. Roy (1963) reported the disintegration of Ceratophyllum even with traces of copper sulphate. Philipose (1959; 1963) found sodium arsenite at five to six ppm useful in clearing persistent infestations of submerged weeds in confined waters, without killing fish. In Australian irrigation systems aromatic solvents have been used for the control of submerged vegetation (Dunk, 1954b), but they are not suitable for fishery waters owing to the high concentrations required for the kill, their extreme toxicity to fish and their prohibitive cost. Similarly, aerolein which is replacing 2,4-D to a great extent in channel weed control (Bill, 1963a) is also very toxic to fish, besides being a potent irritant and under certain conditions an explosive. Aquathol (disodium endothal), which is known to be very effective against submerged weeds, is also out of question for fishery waters because of its poisonous properties and extreme toxicity to fish. In limited yard trials at the Central Inland Fisheries Research Station at Cuttack, it proved very effective against *Hydrilla* in low concentrations, but field trials were not done for reasons stated above. Mitra (1959) obtained complete kill of submerged weeds with superphosphate at 500 ppm. Uprooting of *Ottelia* was obtained with urea at 50-100 ppm and complete kill of *Hydrilla* at 250-300 ppm in yard or field trials in India (see Barrackpore, 1959 - Annual Report for 1958-59). Even with 100-150-200 ppm there was a high percentage of kill. Ammonia evolved and algal blooms which resulted from the treatment were more or less directly proportional to the concentration of urea used. However, both superphosphate and urea are quite costly for general applications and further, urea above 50 ppm also kills fish.

Ramachandran (1959) experimented with anhydrous ammonia and found it effective in giving quick kill of submerged plants like *Hydrilla* and *Najas* when it is injected directly on the infestation. By subsequent work (Ramachandran, 1963a) the techniques of its use were standardized. Because of its quick action, ammonia appears to be suitable for flowing waters as well. Not only it does not leave any toxic residual effect but it can also act as a fertilizer. Though it kills fish, by sectional treatments of thick infestations, useful fish can be saved. However, the treatment is time-consuming and the cost of about Rs400[1] (at Rs3.30 per Kg of chemical) per hectare meter for the chemical alone at 12 ppm (Ramachandran, 1963a) is rather high. Follow-up operations are also necessary to prevent regeneration.

2,4-D has not been generally considered useful against submerged weeds, unless applied along with some sticking agents like methoxome dust or "micronized" sulphur (Dunk, 1953; 1954a; 1955b) and that too after reducing the water level to about half a meter. Srinivasan and Chacko (1962) reported the kill of *Hydrilla* and *Najas* with Dicotox in an area about one meter deep. Field trials at the Central Inland Fisheries, Cuttack, also indicated that plants like *Ottelia* with partially exposed leaves can be killed and uprooted with a surface spray of sodium 2,4-D, but neither the sodium salt nor the ester had any appreciable effect even at reasonably high rates when applied in water containing fully submerged plants.

Mathews (1960) reports that 2,4,5-trichloropropionic acid (2,4,5-TP) in liquid form recently tried in New Zealand waters has checked *Lagarosiphon* and water thyme without harming fish. He suggests that the granular preparation of the weedicide applied at the pond bottom to build up a toxic concentration of two to five ppm in the lowermost 30 centimeters of water should prove useful against rooted aquatics. Preliminary trials by the same author (undated paper) with Diquat and an allied product Paraquat have shown that both are quite efficient in killing *Lagarosiphon*, *Elodea*, *Potamogeton*, *Aponogeton*, *Callitriche*, *Ranunculus* and *Myriophyllum* at 0.5 ppm though *Chara* and *Nitella* are resistant. The weedicides have no harmful effect on fish and stock and do not leave any long-term toxic residue in the soil. They are also stated to be suitable for application in flowing water.

The chief considerations in the use of herbicides in fishery waters are that (i) they should be effective in killing weeds at reasonably low rates of application, not exceeding say about 10 ppm for those applied in water and about 10 kg per hectare for those sprayed on a surface area basis; (ii) they should be cheap and easily available; (iii) they should not be toxic to fish or other biota. If toxic, they should be suitable for localized applications to save fish; (iv) they should not, as far as possible, be toxic to warm blooded animals so that they can be used freely without any hazard to humans and stock animals; (v) they should not pollute the treated water or leave any residual harmful effect which will adversely affect the fertility of the water and soil (salts of heavy metals like copper and arsenic are harmful this way); (vi) their use should not involve special costly equipment and technical personnel; and (vii) they should not have corroding action on metal containers and sprayers and on clothing.

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[1] One U.S.$ = approximately 4.75 Indian rupees in 1966

None of the weedicides currently in use fulfil all these requirements. However, some of them like 2,4-D and allied products and Dalapon appear to possess the maximum good qualities. When used with suitable sprayers, carriers and wetting agents they are effective against most plants emerging above the water surface and in pelleted or granulated form even against submerged plants. Diquat appears promising though further experimentation with it is necessary. Ammonia could also be useful for specific purposes. Economics of aquatic weed control will be discussed later.

4.3.5 Algal blooms and filamentous algae

Very little work has been done on the control of algal blooms in Asia and the Far East though a number of algae, notably blue greens like Microcystis, Anabaena and Oscillatoria and several others infest fish ponds and reservoirs. Control of algae in reservoirs connected with water supplies is usually done by the application of copper sulphate in very low concentrations of 0.025-0.05 ppm in anticipation of blooms or at 0.1-0.5 ppm after the blooms occur. Dunk (1957) states that in Australian storage reservoirs it is not harmful to humans and stock when applied at about 0.1-0.4 ppm to control algal slime, though fish may be affected.

To make copper sulphate effective in productive fish ponds with invariably alkaline waters it has to be applied at high concentrations which is bound to result in fish mortality. This can possibly be prevented by localized applications of the chemical spray in areas where scums accumulate due to wind action as done by Kessler (1960) in Israel. It also appears worthwhile trying in Asian ponds algicides like Monouron, Dichlone, Simazine and Hercules Algicide , which are reported from America to be useful, to determine their suitability and economics.

Chemical control of mat- and scum-forming filamentous algae does not appear to have been attempted in the region.

4.4 Biological control

This is one of the most convenient and frequently the least expensive of the control methods from the point of view of the fish farmer since he need not go in for expensive equipment and chemicals, the fertility of the water body is not impaired and the control is effected side by side with the culturing of fish without reducing the total production.

A number of animals are known to feed on aquatic plants or otherwise cause damage to them resulting in their control or eradication in fish cultural waters. Some of these are herbivorous fishes (Swingle, 1957), rodents like Myocastor coypus , commonly known as nutria (Ehrlich, 1957) and musk-rats (Martin, 1953), sea-cows like Trichechus manatus or the manatee (Allsopp, 1960), geese and ducks (Martin, 1953; Hora and Pillay, 1962; Hickling, 1962), beetles or their larvae, e.g. Galerucella nymphaeae (Smirnov, 1960) and Donacia hypoleuca (Martin, 1953) which forage on leaves or bore into petioles and moth larvae (see Philipose, 1957).

Of these, the herbivorous fishes are the most important as far as Asia and the Far East are concerned since most of the well known and effective herbivorous fishes are found in this region. Ctenopharyngodon idella, the grass carp, a native of China, since introduced successfully in many parts of South East Asia and even in Europe and N. America on a limited scale, has been reported to be the most effective fish in controlling the overgrowth of certain types of aquatic vegetation. In China, for lucrative culture of the fish (Lin, 1940; Ling, 1960) it has to be fed with grass, pond weeds including even Salvinia, terrestrial weeds and vegetables. In a personal communication, Lin states that all fish ponds in China are systematically stocked with grass carp, a fish eating 40-70 percent of its own weight of grass a day, compared to the daily consumption of hay by a cow equal to 10-12 percent of its body weight only. With 30 grass carp per hectare overgrowth of weeds can be stopped whereas with 100 per hectare, the weeds can be totally eradicated. Satisfactory control of submerged weeds has been reported from Japan (Kuronuma and Nakamura, 1958) when 30 fish weighing about 35 kg were stocked per hectare along with other regularly cultured fishes without impairing the production of the latter. Hickling (1962) reports effective control of Enhydrias angustipetala and Chara in Malaccan ponds by the grass carp and another weed eating fish, the tawes (Puntius javanicus). To fatten these fishes he had to encourage the growth of these plants by dressing the ponds with basic slag. Reports from Thailand (Swingle, loc. cit.) also confirm the effectiveness of the fish. In India, Alikunhi and Sukumaran (1964) observed that the fish consumes Hydrilla, Nechamandra (Lagarosiphon), Azolla and Lemna, though between Hydrilla and Nechamandra, the fish showed a preference for the former. Ponds choked with Hydrilla could be cleared within a month by stocking the fish at 300-375/ 78.8-173 kg/hectare. To keep sufficient number of grass carp breeders in a healthy condition it was necessary to collect these plants from other sources and supply regularly in the stocked ponds. Stocked at 125-150 fish/ 175-225 kg/hectare, they could utilize duck weeds at the rate of 1.8 kg per fish per day. In West Pakistan also experiments appear to be in progress to find out the suitability of the fish in controlling weeds in reservoirs. Latest reports from Russia (Aliev, 1963) and the U.S.A. (Avault, 1965) confirm that in these countries also the grass carp controls a wide variety of submerged weeds, rushes, reeds and to a limited extent even water hyacinth.

The age and size of the fish mostly decide the type of weeds controlled and the extent of control (Reich, 1954 and Hora and Pillay, as cited by Swingle, 1957). Fingerlings of 30-50 grams usually feed on duck weeds while larger fish feed on other aquatic vegetation.

The success obtained in India, Taiwan and Russia recently in inducing the fish to breed under controlled conditions, thereby making it easier to build up sufficient stock of the fish, should go a long way in popularising its use for the control of submerged and some floating and marginal weeds. Cutting up of the weeds during feeding and enrichment of ponds with excreta of the fish containing remains of vegetable matter frequently result in the formation of algal blooms (see Alikunhi and Sukumaran, loc. cit.) especially when the ponds contain a large number of grass carp. To keep down these blooms it may be necessary to stock a certain number of Chinese silver carp or any other suitable phytoplankton feeder in the pond.

The grass carp, thus seems to be a very promising biological control agent for Asia and the Far East and possibly other regions. However, large-scale introduction of this fish has to be preceded by a thorough study of the biological effect of this fish on the economic varieties of indigenous fish.

The next best plant-eating fish is Puntius javanicus (see Swingle, 1957; Ling, 1960; Hickling, 1962), principally raised in Indonesia, but introduced in a few other South East Asian countries as well. According to Vaas and Sachlan (1952) it feeds on plant leaves and filamentous algae. Hora and Pillay (undated paper) state that it feeds on plants belonging to the Characeae, Ceratophyllaceae, Polygonaceae, Najadaceae, Gramineae and others. Ling (1960) states how in large lakes and reservoirs of Indonesia, particularly Celebes, troublesome submerged weeds and filamentous algae have been completely controlled by Puntius and Trichogaster, another weed-eating fish. Since it breeds in ponds and is fast growing, it has been considered suitable for the dual purposes of raising fish and controlling soft-leafed aquatic weeds.

A number of species of Tilapia are also known to be herbivorous. According to Hofstede and Botke (1950), though Tilapia mossambica is chiefly a plankton feeder, the adults consume also filamentous algae and higher plants. In Indonesian brackish-water ponds the fish helped in the elimination of filamentous algae. The same species introduced in the Fena Reservoir on the island of Guam some time in 1954 cleared large beds of Potamogeton crispus and Utricularia within about one and a half years (Vernon E. Brock, personal communication, 1956). At Cuttack, India, where the fish has been under study for several years, ponds intensively stocked with the fish have been generally free of soft submerged vegetation and filamentous algae. Other species which are known to be even more effective are, T. melanopleura (see Timmermanns, 1955), T. nilotica (see Avault Jr., 1965) and T. zillii. In the ponds at Malacca, the recently imported T. zillii has been found more effective than T. melanopleura in controlling Fimbristylis after initial cutting (Prowse, personal communication). These tilapia, though useful in controlling filamentous algae like Pithophora and soft-leafed submerged aquatics, are not so effective as the grass carp or tawes. Tilapia is also not generally considered a good pond fish because of its frequent reproduction resulting in over population and consequent reduction in size of individuals.

The gouramy, Osphronemus gorami, is also considered useful in controlling some submerged aquatic weeds since it not only makes use of them for feeding, but also cuts up some of them for making its nest (Villadolid, 1936). Ganapati (1947) states that it checks submerged vegetation in irrigation wells, fish ponds and reservoirs. However it is not as effective as the above-mentioned fishes and it is also difficult to raise it on an extensive scale.

The only other fish that deserves mention in this connection is the common carp, Cyprinus carpio, which is now cultivated in a number of South East Asian countries. Though it does not consume much of aquatic weeds, it helps in uprooting the plants in its search for bottom living insect larvae and worms and also making the water very turbid in the process, thereby suppressing submerged weeds. Ganapati (1947) and Srinivasan and Chacko (1952) refer to its usefulness in some Indian waters. According to Pruginin and Lipshitz (1957) heavy stocking (4,000 per hectare) with the carp helped in the control of Myriophyllum in a pond in Israel. Avault Jr. (1965) reports that the mirror strain of common carp has shown potentially good results in the U.S.A. also. However, further work on its usefulness in Asia as a weed control agent appears to be warranted.

Next to herbivorous fishes the most important animals for the control of weeds available in Asian countries are ducks and to a limited extent geese. According to Hora and Pillay (1962), ducks feed on some water weeds and a few of them in a pond might help in their control. Hickling (1962) states that geese will keep grass on pond banks trimmed short. From his experience in Rhodesia Van der Lingen also is of opinion that apart from controlling all types of undesirable weeds when densely stocked, ducks manure ponds and provide a side income from their meat. It appears worthwhile experimenting on the use of these birds as regular weed control agents in countries of Asia where other suitable biological agents are not available at present.

The nutria, a native of South America, now introduced in some parts of Europe and in Israel has also been considered (Ehrlich, 1957) an effective biological control agent since it destroys a number of reeds and rushes including the hardy Phragmites and Typha. Though its habit of burrowing into embankments and the difficulty of raising sufficient numbers of the animal could be positive disadvantages, it is harmless to fish, its protein and vitamin rich excreta enrich the water and its meat and skin provide a side income. It appears worthwhile trying it on an experimental scale in South East Asian countries having persistent trouble from hardy marginal weeds. The same may not hold good for the manatee claimed by Allsopp (1960) to be effective in the control of a number of weeds including water hyacinth in British Guiana because of its large size and delicate nature involving transport problems, its slow reproduction and liability to be poached upon easily.

The use of insects or their larvae as control agents for aquatic weeds is still in its infancy in Asia and the Far East. Limited control of Pistia has been observed in experimental pots and ponds in Bengal (see Philipose, 1957) during winter by foraging caterpillars of an unidentified moth. Dr. V.P. Rao of the Commonwealth Institute for Biological Control, Bangalore, is reported (Poling and Barr, 1965) to be experimenting with a grasshopper and two caterpillars for the biological control of water hyacinth. In this context the report from Russia by Smirnov (1960) on Galerucella nymphaeae, a chrysomelidan beetle, as a voracious consumer of water lily is interesting. The larvae of Galerucella is known to be injurious to a number of land weeds as well.

As it stands at present, the Chinese grass carp, the tawes and to a lesser extent tilapia appear to be the most tried and most suitable biological weed control agents for Asia and the Far East.

Another biological agency for the control of submerged weeds is some water weeds themselves. The action of the latter is one of shading or to some extent one of competition. Yard experiments and field observations at Cuttack, India (see Barrackpore, 1953 - Annual Report for 1952-53; Philipose, 1959) and in East Pakistan (Ahmad, 1954) have indicated that a surface cover of plants like Pistia or water hyacinth is very useful in clearing noxious submerged weeds in fish ponds. However, one has to be very careful in the selection of the weed for shading. Unless it is in a small confined water area it is not advisable to use water hyacinth for this purpose. Plants like Pistia and Salvinia, which can easily be removed with seines (Philipose, 1963) once the control of the submerged weeds is effected, are preferable. The obvious disadvantage is that it is difficult to bring sufficient quantities of these weeds from other sources or to propagate them in the ponds so as to obtain a thick cover within a limited period. This method can therefore be employed only in small water bodies with persistent infestation of submerged weeds. Localized shading is also possible by enclosing the floating plant within a bamboo or wooden floating framework and keeping it in areas with infestations of submerged weeds.

The practice of the Bengal fish farmers (Alikunhi et al.,1952) of introducing Lemna in nursery ponds infested with permanent algal blooms to kill these algae and convert them into more useful fish food organisms appear to be ideal for the control of noxious algal blooms in such ponds.

Periodical fertilization of ponds containing submerged vegetation (Smith and Swingle, 1941) with inorganic fertilizers to encourage the growth of phytoplankton or filamentous algae to shade and kill the submerged vegetation is another possible method. In preliminary observations at Cuttack, India (see Barrackpore, 1958-60 - Annual Reports for 1957-58, 1958-59 and 1959-60) it was found that urea at 50-250 ppm could not only kill submerged weeds in varying degrees by its direct action, but it could also help in the production of algal blooms, the intensity of which was frequently directly proportional to the concentration of urea used. However, in South East Asian countries where the inorganic fertilizers manufactured are at present not sufficient even for cereal crops, this method is quite expensive and not always practicable. Also, the intense illumination which prevails for at least six to eight months in the year could make the algal screen ineffective unless it is sufficiently thick and persists for a fairly long period.

In many South East Asian countries fertilization of fish ponds is usually done with organic manures, frequently by turning sewage into them (see Prowse, 1962). Though this method has certain obvious disadvantages, submerged vegetation do not normally flourish in such ponds because of the high turbidity caused by phytoplankton, thus serving the dual purposes of producing fish food organisms and controlling submerged aquatic weeds. According to Ling (1960), fertilizing heavily with organic manures during the pre-stocking preparation period is one of the reasons for limited growth of submerged plants in ponds in China.

4.5 Combination methods

Though the methods discussed above could be convenient for use against particular infestations, in actual practice one or more of them are frequently combined for better efficiency, to meet special requirements and for reduction of costs. Mechanical and chemical methods also invariably entail the use of manual labour to a great extent in operating equipments and in the final disposal of cleared weeds.

In chemical spraying of floating weeds like water hyacinth, sometimes only a softening dose is desirable for subsequent easy removal of the affected weed by manual or mechanical means so as to avoid pollution of the water by its decomposition. When ammonia is used against submerged weeds (see Ramachandran, 1963a; Philipose, 1963) some manual or mechanical removal a few days after treatment helps in getting better clearance, preventing regeneration and reducing the cost. Stocking of plant-eating fish would also be easier and more effective if rank infestations of submerged weeds are initially thinned out by mechanical or chemical methods.

5 GENERAL CONSIDERATIONS

For successful control of weeds in fishery waters it is necessary to take into consideration some of the following aspects.

5.1 Selection of a method

In selecting a method of control one has to consider the nature, depth and approaches of the water area, the type, age and density of infestation, cost of labour, mechanical equipment and chemicals, the feasibility of the method under local conditions, possible after effects on the existing fishery and the purpose for which the clearance is made. Thus, a method which is feasible or acceptable in one place or country may not be so in another, making it necessary to treat each infestation as an individual problem.

While manual methods appear suitable for floating, marginal and emergent weeds of small bodies of water in most countries of the region, chemical-cum-manual or mechanical methods appear to be more suitable against hardy marginal plants of large bodies of water. Large infestations of water hyacinth are more easily controlled by the application of 2,4-D than by any other known method. Submerged weeds are best controlled by herbivorous fishes, if necessary after initial thinning by mechanical or chemical means.

5.2 Selection of the time

This is as, if not more, important than the method employed. In selecting the best time one has to know the most vulnerable period in the life history of the weed, the period of intensive production of reproductory units by the weed or their germination and the meteorological conditions under which a chemical will give maximum kill (see also, Martin, 1953).

Thus, in plants with well marked seasons of flowering and fruiting (e.g. *Najas*, *Trapa*, or even water hyacinth) or turion formation (e.g. *Hydrilla*), it is advantageous to clear them before the fruits, seeds or turions are fully formed and shed. It is also known that cutting of plants like water lilies, *Typha* and *Phragmites* when they are actively flowering gives the best result. Similarly, submerged plants are more susceptible immediately after floods when they had strained their utmost to keep pace with the rising water level. Water hyacinth is most susceptible during its active vegetative growth which takes place during the monsoons or summer. So, a complete knowledge of the autecology and physiology of the more important weeds in the region is very essential for their successful control. Though some steps in this direction have been taken in India, Australia and New Zealand, co-ordinated work covering the entire region appears necessary.

5.3 Economics of control by different methods

As already stated, the economics is an important consideration in selecting the method of control. However, cost of clearance by any of the methods discussed varies not only from country to country but also from place to place and time to time in the same place depending on several factors. Readily available figures for some of the common methods are given below.

In India (see Philipose, 1963) cost of single clearance of thick infestations of water hyacinth, *Pistia* and duck weeds from small water bodies by manual labour (at Rs.1.50 for six man hours) has been estimated at approximately Rs.150, Rs.75 and Rs.52.50 per hectare respectively whereas that of *Hydrilla* and *Najas* from a similar area 1.5 meters deep came to Rs.240 for a single clearance and Rs.750 for three to four clearances in the course of one year. Ramachandran (1963b) estimated the cost of labour for clearing a rank infestation of water hyacinth about 66 cm high from a large water area at Rs.875 per hectare (at Rs.3/- per six man hours). Clearance of submerged weeds (see Philipose, *loc.cit.*) with power winch and sodium arsenite from a 1.5 meter deep area cost Rs.180-235 per hectare and treatment by ammonia (at 9 ppm) supplemented by manual cleaning about Rs.490. Clearance with 2,4-D cost Rs.135-150 for water hyacinth. Water lilies were cleared with 2,4-D or by repeated cutting at about Rs.120. Srinivasan and Chacko (1952) obtained clearance of submerged weeds with 2,4-D (dicotox) at about Rs.175 per hectare meter and Banerjea and Mitra (1954) with copper sulphate and sulphuric acid for the same cost.

Dassanayake and Chow (1954) report that it costs about Rs.300 per hectare for the clearance of *Pistia* by human labour in Ceylon, as against Rs.40-50 with phenoxylene-30 mixed with teepol.

In Thailand, for cutting floating masses of weeds into convenient patches and pushing them down flooded channels it cost only about 12 U.S. dollars, whereas for dragging them into shallow areas with wire ropes and for subsequent hand removal or burning it cost $250 per hectare.

In Australian irrigation and drainage systems, *Phragmites*, *Typha*, *Juncus* and *Eleocharis* were cleared (Dunk,1953; 1954a; 1955) with oil-based esters of 2,4-D at a cost of about £25-32½ per ha. Though high rates of soil sterilants at high costs were necessary for clearance of some marginal weeds, the still higher costs of manual labour and mechanical methods justified their use.

Figures for other countries are not readily available. The meagre data available for the region indicate the need for collecting more information on a standard basis as discussed below.

5.4 Standardization of techniques

5.4.1 Assessment of weed infestations

Much of the discrepancies in weed control reports are due to improper assessment of the density of weeds. Though floating and marginal weeds can be easily assessed by the standard quadrat (1 sq. m) estimations by weight as done in land weeds, it becomes more difficult to estimate submerged and emergent weeds especially in deep waters (also see Kuronuma and Nakamura, 1958). In the absence of a better method, in quantitative work done at the Central Inland Fisheries Research Sub-Station, Cuttack, the method followed was to collect all the weeds enclosed by a light cubic metal frame of standard size placed at random in the infested area and to estimate their fresh and air dry weight later. However, this method is laborious and not convenient for deep waters. The ease with which a drag net can be operated after clearance of submerged and emergent weeds has also been taken as the criterion of the extent of clearance in some instances.

5.4.2 Chemical spray and other control measures

Even in the case of well tried weedicides like 2,4-D for the control of the same plant (e.g. water hyacinth), frequently there has been conflicting reports on the results obtained in Asian countries. This has been mainly due to differences in formulations involving varying active ingredients, in the sprayers and nozzles, co-solvents or wetting agents, carriers and dilutions or volume of spray and coverage or differences in the age, size and density of the infestations or the season or meteorological conditions under which they were sprayed. This calls for standardization of techniques of application for at least the common weedicides used against specific weeds. The same holds good for control by common herbivorous fishes in which uniform rates of stocking and comparable sizes and weights of the fish have to be employed against similar infestations.

5.4.3 Estimation of economics

Here also uniform methods of assessing the cost of clearance have to be adopted in all countries of the region so that they are comparable. Thus, the cost of chemical (commercial as well as active ingredient), hire or depreciation charges of sprayers and mechanical equipment, incidental expenses and cost of labour in terms of man hours employed, per hectare or hectare meter, as the case may be, preferably on an annual basis, should be given to assess the real economics.

5.5 Utilization of aquatic weeds

Though excessive vegetation in fishery waters is no doubt a menace, one cannot overlook the fact that some of these plants can be put to use one way or the other. Thus, apart from the usefulness of some of them in fish ponds, aquatic plants have been used in the preparation of agricultural composts or as fodder, vegetables, medicinal plants and raw materials for some cottage industries. Such uses bring the fish farmer a side income thereby reducing the cost of weed clearance and providing the necessary incentive. Interest has revived in such utilization (see Pirie, 1960; Singh, 1963) because of the mounting costs of manual, mechanical and chemical clearance and other factors.

Even such a noxious weed as the water hyacinth has been reported to be useful for the manufacture of potash and alcohol (Day, 1918; Sen, 1928), as fodder (Hora, 1951; Hossain, 1959; Ling, 1960) as compost (Finlow and McLean, 1917; Watson, 1947;

Basak, 1948), as spawning bed of some tropical fishes (Bose, 1945) or even as vegetable. However, its use as compost and fodder only merits consideration. It is reported to yield a valuable compost and is used for that purpose in several South East Asian countries. According to Singh (1963), not only water hyacinth but also Pistia, Hydrilla, Ottelia and Najas which grow abundantly in ponds can be converted into useful composts. Ling (1960) states that a number of shore plants can be applied to the pond bottom as green manure during pre-preparation of ponds or tied into bundles and placed along the edge of the water to decompose.

Tender water hyacinth has also been considered as a good fodder, especially for pigs. So, they help in pig farming near pond sites in East Pakistan, Malaysia, China Hong Kong and other South East Asian countries. Typha elephantina and the duck weeds, as their names suggest, are favourite items of food of elephants (Biswas and Calder, 1937) and ducks respectively. The usefulness of grasses and pond weeds for feeding grass carp has already been mentioned.

Fruits, rhizomes, leaves and sometimes flowers of a number of aquatic plants like Trapa bispinosa, Nymphaea and Nelumbo spp., Euryale, Nymphoides indicum, Aponogeton monostachyon, Nasturtium officinale, Herpestis monnieria, Jussiaea repens, Ipomoea aquatica, Limnophila spp., Ceratophyllum demersum, Hydrolea zeylanica, Pistia stratiotes, Typha angustata, Hygrorhiza, Scirpus grossus and Cyperus auriculatus serve either as vegetables for certain sections of the people in India and some neighbouring countries (see Biswas and Calder, 1937) or for indigenous medicine (Rao, 1914). Job (1950) and Malik (1961) state that it is profitable to cultivate some of these, though this can be done only if it does not affect fish production.

Aquatic plants have also been used for other purposes. The stems of Aeschynomene aspera have been used in India for making rafts, fishing boats, toys and solar hats, while the leaves or stems of Typha, Phragmites, Cyperus corymbosus and C. tegetiformis have been used either for thatching houses or making mats and screens. Moist leaves of Hydrilla and Vallisneria were formerly used in India to cover molasses in refining sugar. Nelumbo and water lilies are collected for their flowers and Vallisneria, Lagarosiphon or Cabomba as aquarium plants.

Apart from water hyacinth, such plants as Ceratophyllum and Myriophyllum are commonly used in China for the attachment of eggs in the culture of common carp (Hora and Pillay, 1962). In India Hydrilla and Najas have been generally used in collecting eggs of this carp.

Thus, by controlling unwanted plants and exploiting useful ones it should be possible to strike a proper equilibrium to the advantage of fish culture in confined waters.

6 SUGGESTIONS FOR FUTURE WORK

Considering the population explosion that is taking place in Asia and the consequent urgency for utilization of all available water resources for intensive fish culture, weed control should be given its due importance in future developmental programs relating to fish culture.

In selecting a method of control for water weeds, due consideration should be given to all pros and cons, including the socio-economic conditions of the people of the country concerned. Even though traditional manual and management methods have still their place in the economy of most countries, some well tried chemical methods like 2,4-D treatment and control by certain herbivorous fishes have come to stay.

Since the success of weed control depends to a large extent on its timing based on detailed knowledge of the weeds including their susceptibilities, co-ordinated studies on the autecology and physiology of the noxious weeds, which have not received such attention so far, appear necessary to cover all the weeds in the region.

For obtaining more uniform and comparable results, methods of field assessments of aquatic vegetation, common chemical spray techniques for each type of infestation, stocking rates, size and weights of common herbivorous fishes and methods of calculation of economics have to be standardized and made available to the common man in an easily understandable form.

Further experimentation to evolve new methods from indigenous materials, to improve existing methods and to try, in the region, methods reported to be effective in other regions appear to be essential to maintain steady progress. Intensive studies on insects as biological control agents should be encouraged and the possibility of introducing nutria on an experimental scale in some of the countries of the region looked into.

Year round maintenance and proper and timely utilization of cleared waters is sound economy since they prevent reinfestation by an already cleared weed or succession by a new set of equally or more noxious weeds.

All possible steps, including legislation if necessary, should be taken to prevent the spread of noxious weeds to new areas or to control or eradicate them from an already infested area, not only in the interests of fish culture but also of sanitation and health.

Finally, all possible avenues of utilization of water weeds have to be explored so as to provide the maximum incentive to the fish farmer to effect their clearance. Alternatively, the weeds could be returned to the waters from which they have been removed in a suitable form for better production of fish.

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CONTROL OF POND WEEDS

by

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Abstract

The author discusses the importance of pond weeds and weed control by chemical, mechanical and biological methods. The wide use of herbivorous fish in African fish culture is a factor of special importance. Examples of results achieved with selected herbicides are given and the need for further work on their toxicity to fish and effectiveness in different types of waters suggested. Mechanical methods are of value in smaller waters.

The value of biological methods is stressed as the most promising avenue of research. Further investigations on differences in the efficiency of different strains of herbivorous fish is necessary. The establishment of an equilibrium whereby vegetation is returned rapidly to the biological cycle in the pond is the aim of biological control methods.

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LUTTE CONTRE LA VEGETATION AQUATIQUE

Résumé

L'auteur examine l'importance de la végétation aquatique et la lutte contre les plantes envahissantes par des méthodes chimiques, mécaniques et biologiques. L'utilisation répandue de poissons herbivores en pisciculture africaine est un facteur d'importance spéciale. L'auteur cite des exemples des résultats obtenus avec certains herbicides et préconise de poursuivre les travaux sur leur toxicité pour les poissons et leur efficacité dans différents types d'eau. Les méthodes mécaniques donnent de bons résultats dans les petits plans d'eau.

Il est souligné que ce sont les méthodes biologiques qui paraissent offrir à la recherche les perspectives les plus intéressantes. Il faut étudier plus avant l'efficacité relative des différentes espèces de poissons herbivores. Les méthodes biologiques visent à établir un équilibre au sein duquel la végétation est rendue rapidement au cycle biologique de l'étang.

LUCHA CONTRA LAS MALAS HIERBAS EN LOS ESTANQUES

Extracto

El autor examina la importancia de las malas hierbas en los estanques y la lucha contra las mismas por medios químicos, mecánicos y biológicos. El amplio uso de los peces herbívoros en la piscicultura africana es un factor de importancia especial. Cita ejemplos de los resultados logrados con determinados herbicidas y sugiere la necesidad de investigar más a fondo acerca de su toxicidad para los peces y su eficacia en distintos tipos de agua. Los métodos mecánicos son útiles en las masas de agua de pequeña extensión.

Pone de relieve el valor de los métodos biológicos como orientamento más prometedor de la investigación. Son necesarias nuevas investigaciones sobre las diferencias en cuanto a eficacia de las los distintos tipos de peces herbívoros. El objetivo de los métodos de lucha biológica es el establecimiento de un equilibrio mediante el cual la vegetación se restituye rápidamente al ciclo biológico en el estanque.

1 INTRODUCTION

The control of pond weeds has posed problems in European and American pisciculture, and in the tropics is potentially a graver problem since in many cases ideal situations exist for the prolific development of such plants. However, in fish ponds of the normal small size in typical African fish culture, they have, by and large, presented no serious problem in properly managed ponds. In certain rivers and larger bodies of standing water a serious menace is often constituted by overabundant vegetation but in most cases means have been found to combat this. There is in many parts of Africa the multipurpose use of storage reservoirs normally used both for farm irrigation and fish raising and it is in these larger waters that problems more often arise. It will become apparent that a prime factor in weed control is the widespread use of herbivorous *Tilapia* and in this respect fish culture in Africa enjoys an advantage over those in other areas. In this review it is intended to take into account only methods and remarks applicable to pond fish farming and the use of moderately sized farm dams, and not to discuss methods of combatting large scale infestations as for example the *Salvinia auriculata* on Lake Kariba.

2 GENERAL CONSIDERATIONS

Wild (1961) has produced a valuable handbook which deals with the identification, occurrence and suggested means of control of harmful aquatic plants in Africa and Madagascar. He lists 14 species of major importance including five which are mainly troublesome in irrigated crops. Four species are free-floating and five species rooted aquatics. A further five species of free floating plants are listed as potentially dangerous and 16 of rooted likewise. Five species of plants dangerous in other parts of the world but not known in Africa or Madagascar are included.

The effect of excess vegetation is summarized by van der Lingen *et al*.(1960), De Kimpe (1956 *a* and *b*) while Fish (1955) draws attention to the effect of dense growths of water lilies (*Nymphaea*) in hindering the mixing of the water mass in dams, and consequent deoxygenation. He points out that the stocking of *Tilapia* in such dams may be unsuccessful because of the lack of oxygen resulting from heavy covers of this weed. Lemasson (1957) discusses ancillary effects of excessive weed growth in relation to the harbouring of mosquito larvae. This, of course, is also true for the snail vectors of bilharziasis.

A considerable body of knowledge on the control of undesirable and excessive vegetation and experience from other parts of the world is available for the fight against weeds in Africa (see Timmermans, 1961). Various firms specializing in herbicides have produced an arsenal of chemicals but these however are not always easily obtainable in Africa and in many cases the cost limits their use by fish farmers.

The types of pond vegetation in most parts of the Continent are similar although certain species or groups with different habitats may vary in importance from place to place. Mortimer (1961) gives an account of the most common vegetation in conservation dams in Zambia and finds a similar pattern of occurrence in most of these on the plateau of this country. The extent and importance of the different elements - fringing, floating-leafed, free-floating and submerged plants depends largely on local conditions and physical considerations of the water body in question. In a recent review of tropical aquatic vegetation Bard (1965) discusses various methods of combatting undesirable vegetation, particularly in larger waters.

In this review it is convenient to adhere to the classification of methods conventionally adopted, namely:-

i) Chemical control
ii) Mechanical control, and
iii) Biological control.

In a number of cases the best methods of approach are undoubtedly combinations of at least two and possibly all three of these, particularly since in the case of the first two, one treatment alone is rarely sufficient. Single treatments using either or both of the first two methods followed by the use of an appropriate method (in most cases the use of a herbivorous fish) involving biological control have much to recommend them. For example in the case of dams in Uganda, biological control with fish is precluded until conditions for the establishment of a fish population have been achieved by the removal of coarse vegetation.

3 CHEMICAL CONTROL OF VEGETATION

Chemical methods of eradication or control are available in varying degrees of efficiency for most types of aquatic vegetation. Possibly its greatest value lies in the control of fringe vegetation and of vegetation not easily controlled by biological means, as for example _Typha_, _Cyperus_, _Scirpus_, _Juncus_ and some of the floating-leafed species.

De Kimpe (1956b)gives an account of the use of various herbicides, methods of application and results. In a series of investigations he made use of the following:-

Experimental herbicide (un-named)	
2,4,5-T.	Trichlorophenoxyacetic
T.C.A.	Sodium trichloroacetate
2,4-D.	2.4. dichlorophenoxyacetic acid
C.M.U.	3- (p Chlorophenyl)-1,1.dimethyl urea

Although he does not give firm dosage recommendations he has some interesting remarks to make and points out the necessity of a critical evaluation of costs. In regard to the fringe vegetation rooted in the mud, he finds _Typha_ difficult to eliminate as this is frequently so dense that many plants escape treatment. He suggests a lowering of the water level before treatment with the restoration to normal level afterwards. _Echinochloa_ gives the same response to herbicides in water or when exposed. Both for _Jussiaea_ and _Nymphoides_ he suggests drainage and spraying while these are exposed. He notes that _Jussiaea_ provides a shelter for mosquito larvae and that its destruction will remove the hazard of mosquitoes. The rotting vegetation gives rise to a good production of plankton in the pond. The microflora and fauna are not affected. De Kimpe summarizes his experiences as follows:-

Vegetation	Treatment
Typha	2,4-D. or 2,4-D. and T.C.A. mixture
Scirpus	C.M.U.
Echinochloa	C.M.U. or 2,4-D./T.C.A.
Jussiaea	semi emergent C.M.U., 2,4-D., 2,4-D./T.C.A. totally emergent 2,4-D./C.M.U., 2,4-D., T.C.A.
Cyperacea	2,4-D. and T.C.A.

van der Lingen _et al_.(1960) in a review of methods of weed control divide the chemicals into:

a) Inorganic chemicals - e.g. Sodium arsenite
b) Organic chemicals - e.g. Xylene
c) Auxin type regulators - 2,4 -D
d) Other growth regulators - C.M.U.
e) Contact herbicides - P.C.P.
f) Algicides - Rosin amine D acetate

The majority of emergent weeds are controlled by Dalapon (Sodium 2,2 dichloroproprionate) at application of 10 kg/ha approximately. *Polygonum* which is frequently a pest in conservation dams in Rhodesia is said to be susceptible to 2,4-D at 3 kg acid equivalent per ha or 2,4,5-T at 3 kg per ha. Floating weeds such as *Eichhornia* are controlled by similar concentrations of 2,4-D. Weeds with floating leaves such as *Nymphaea* species have been controlled by use of granular 2,4-D at 10-15 kg per ha. For underwater or submerged weeds sodium arsenite is suggested at four to five ppm. The authors quote toxicities of some herbicides to fish. However, this is a field in which it is quite clear that much further work is required. In many cases the concentrations of herbicides necessary for vegetation control may well be lethal to fish under prevailing physico-chemical conditions.

Van Schoor (personal communication) has some very interesting results from recent trials in Cape Province of the Republic of South Africa. This worker has paid particular attention to the effect of herbicides on fish and finds that while the Amyl ester of 2,4,5-T (approximately 0.5 kg acid equivalent/l) seriously affects broad-leafed emergent aquatics, this has a long-lasting ill-effect on fish. Deaths in laboratory tests with 0.2 ppm herbicide occurred from one to five months after application. Van Schoor points out that it may be either the hormone itself or its concomitant solvents that cause death but suspects the former. The use of 2,4,5-T cannot therefore be recommended. However, 2,4-D is not as dangerous but a weak concentration only of this is suggested, namely six parts per thousand of chemical with the addition of a wetting agent at two to three times the recommended rate. *Nymphaea*, *Limnanthemum* and *Myriophyllum* are successfully controlled, particularly if the pond can be drained prior to spraying.

Simazine is found by van Schoor to be harmless to fish and may be a useful herbicide, and has been used in America against rooted aquatics with floating leaves (van der Lingen *et al.*, 1960). However, this suppresses algal growth completely and may cause serious interference in the food production in a pond.

Van Schoor finds the sodium salt of 2,2 dichloropropionic acid (Dalapon) 85 percent active ingredient suitable against narrow-leafed marginal aquatics if mixed 0.5 kg/50 l approx. and applied with a wetting agent. No tests of the toxicity are described by him but it is said that 1,000 ppm of this is the lethal limit (van der Lingen *et al.*, 1960).

Bard in his review (1965) points out that more than one treatment is necessary in chemical control, which opinion is widely held, and remarks that the cost of control by chemicals that are not noxious to fish is high. Therefore, he says, unless there is a marked drop in prices it is only in cases of urgency such as keeping rivers navigable, that they are justified.

4 MECHANICAL CONTROL OF VEGETATION

Control of excessive vegetation by mechanical means gives scope for great ingenuity and inventive ability and many devices have been suggested for this. Some simple methods have proved very effective. From experience in Rhodesia hand removal and mechanical means will, after repeated attempts result in eradication, particularly if combined with one or both of the other methods. Some methods found to be efficient in practice are given by van der Lingen (1959; van der Lingen *et al.*, 1960). These vary from the use of steel cables, cutting chains and modifications of scythes to hand operated and mechanically driven cutters. In small ponds, particularly, this is the most appropriate method of weed eradication. In larger ponds the action of a hand driven double bladed scythe mounted on an upright pole in a punt has proved successful and economical. All the vegetation removed can be composted and used as fertilizer or in some cases fed to pigs and poultry, while still fresh. Mr. P.D. Proude, Chief Fisheries Officer, Uganda, states that on the Kajansi fish farm *Pistia* is effectively controlled by mechanical means and that no chemicals have been used. Control by mechanical means must always take into account the possible germination of spores and seeds. In some cases the handcutting of *Typha*, *Polygonum*, etc. done at the wrong time may actually result in a greater infestation than before.

5 BIOLOGICAL CONTROL OF VEGETATION

It is perhaps in this sphere that the most rewarding and satisfactory results are to be achieved and that research can be most profitably pursued. The attainment of a biological equilibrium whereby the energy trapped by vegetation is returned to the biological cycle in the water by a relatively rapid process has great importance in the maintenance of fertility in fish culture and in the continuing high yields of fish crops. Already there are grounds for recognizing success in the use of herbivorous fish and the extension of the biological control involving other animals is making progress.

Hey (1952) suggested some years ago the control of vegetation by what is basically a biological method, namely the increasing of plankton by fertilization with a consequent diminution of light intensity under water and the suppression of the growth of submerged aquatics. Although this practice seems to have had success in America where it originated, it has not been widely used in Africa. However, it is true to say that in ponds which are properly managed this method of control is automatically assured. There is, however, a growing awareness among fish culturists that dense plankton development is not indicative of ideal conditions for fish feeding on epiphytic and bottom algae and this argument therefore loses some force.

Tilapia melanopleura and *Tilapia zillii* are noteworthy fish in the control of vegetation. De Bont (1952) records that *T. melanopleura* can clear *Typha*, *Leersia*, and *Scirpus* and that stems of *Carex* will be cut if large numbers of *T. melanopleura* are stocked. It appears that there are wide variations in the ability of this fish to control weeds and in its choice of different types of vegetation.

It has been noticed that in some cases the removal of the softer vegetation by *T. melanopleura* may have led to increasing spread of the harder ones. Nevertheless it must be conceded that the role of *T. melanopleura* and *T. zillii* is particularly important in the control of softer vegetation and possibly in preventing the re-establishment of infestations controlled by other means. In other parts of Africa successful control is reported using these fish. Van der Lingen (1959; van der Lingen *et al.*, 1960) and Mortimer (1961) mention the control of *Chara*, *Najas* and other submerged vegetation by *T. melanopleura*. The Chief Fisheries Officer, Mr. C.E.P. Watson (personal communication) in Kenya states that most of the weed control there is effected by *T. zillii* and *T. melanopleura* and that dams of 2-10 ha formerly choked with weeds have shown total eradication two and a half to three years after stocking. It is interesting to note that in the Annual Report of Kenya Fisheries 1960 it is mentioned that *T. melanopleura* is a more efficient weed eater and is able to thrive at higher altitudes than *Tilapia zillii*. However, it is felt that in many cases the latter is the more desirable fish since it breeds less prolifically and does not result in the rapid overpopulation of waters. Both these fishes are stated to interfere with other fish (also found in some cases in Rhodesia) and it is suggested that appropriate methods of controlling them should be further studied.

In the Transvaal Province of the Republic of South Africa, Lombard (personal communication) reports that *Tilapia rendalli* (*melanopleura*) is effective in controlling submerged vegetation and that in carp ponds no weeds are found. Carp being a bottom feeder is likely to destroy rooted aquatics.

Since harder weeds and others such as *Pistia*, *Nymphaea*, *Echinochloa* and *Carex* are not generally controlled by phytophagous fish other means have also been investigated. The value of domestic waterfowl has been found to be great and ducks and geese particularly useful (Le Roux, 1955; van der Lingen, 1959; van der Lingen *et al.*, 1960). This method has the advantage that the more resistant vegetation is transformed to fish food and manure.

Bard (1960; 1965) mentions some interesting results from the introduction of the coypu (*Myocastor coypus*) in the Cameroon. In five months a pond of 53.5 ares [1] which was more than four-fifths overgrown with *Echinochloa* was cleared by about a quarter by 30 young coypu and completely cleared in 14 months. His experiences indicated that the coypu did not seriously damage adjoining vegetable gardens and rarely strayed more than 300 m from water. This author also mentions that the manatee *Trichechus manatus*, a mammal, may be of value in weed control but has the disadvantage of rarity and vulnerability to attack. In addition to being a weed control agent, the coypu is a source of food, commercially important pelt and valuable manure.

There are valuable contributions to be made to the increase of the food supply by such methods and quite clearly a wide field of investigation in the biological control of water weeds is open.

6 CONCLUSION

In the field of chemical control it is clear that careful laboratory and field work is required on the toxicity of chemical herbicides on different fishes under differing water and environmental conditions. The effect on other aquatic fauna and flora of importance as fish food also requires further investigation.

Mechanical means alone are not satisfactory but no doubt various ingenious devices will continue to find use.

In the field of biological control, particularly in larger waters, much work remains to be done. The preferences of different strains of the same species of fish for vegetation and their weed-eating capabilities will explain some of the conflicting results obtained. These too are likely to differ under varying conditions. The understanding of the relations of the various components in a complex and dynamic system will lead to the possibility of establishing a balanced equilibrium of vegetation and vegetation-eating fish which can be of great advantage to the fish culturist.

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[1] One are = 0.01 ha

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VII/R-5

LE CONTROLE DE LA VEGETATION AQUATIQUE DANS LES ETANGS D'ELEVAGE (EUROPE)

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Résumé

Dans le cycle biochimique d'un étang d'élevage, où l'alimentation n'est pas exclusivement artificielle, la végétation aquatique constitue un maillon indispensable. Toutefois, par leur envahissement, beaucoup de végétaux sont nuisibles et un contrôle régulier s'impose. On cherche surtout à développer le phytoplancton. Dans les étangs négligés depuis longtemps un nettoyage et un dévasement coûteux sont nécessaires. En pisciculture, le contrôle de la végétation aquatique doit être un travail d'entretien normal et régulier.

En Europe, le contrôle de la végétation par des moyens biologiques n'a que des possibilités limitées. L'introduction de poissons exotiques permet un certain espoir. Parmi les méthodes mécaniques, le faucardage motorisé, indispensable pour l'exploitation rationelle de pisciculture assez étendues est largement utilisé et efficace contre la végétation palustre. Le contrôle des végétaux palustres au moyen d'herbicides semble être une méthode rationnelle qui gagne lentement du terrain. La lutte chimique contre les végétaux flottants et submergés a fait de réels progrès ces dernières années, mais beaucoup de problèmes restent encore à résoudre.

VII/R-5

CONTROL OF AQUATIC VEGETATION IN FISH PONDS IN EUROPE

Summary

In the biochemical cycle of a fish pond, in which both natural and artificial foods are available to the fish, aquatic vegetation is indispensable. Some plants, however, are so prolific as to invade the entire pond and therefore require regular control, the main aim being to allow phytoplankton growth. In long-neglected ponds costly cleaning and dredging become necessary. In piscioulture the control of aquatic vegetation must be a regular operation.

In Europe biological control offers only limited possibilities, another means of control being the introduction of exotic fish. As for mechanical methods, power clearing of weeds, indispensable for rationalization of the work in fairly large fish ponds, is commonly and effectively practised to control marshy vegetation. Another method for control of the latter, which is slowly coming into use, is the application of herbicides. Chemical control of floating and submerged vegetation has made real progress in recent years, although many problems remain to be solved.

EL CONTROL DE LA VEGETACION ACUATICA EN LOS ESTANQUES DE CRIA (EUROPA)

Extracto

En el ciclo bioquímico de un estanque de cría en que la alimentación no sea exclusivamente artificial, la vegetación acuática constituye un eslabón indispensable. Sin embargo, por su carácter invasor, muchos vegetales son nocivos, por lo que se impone su eliminación regular. Sobre todo, se intenta desarrollar el fitoplancton. En los estanques descuidados desde hace mucho tiempo son necesarios una limpieza y un vaciamiento costosos. En piscicultura, el control de la vegetación acuática debe ser una labor normal y regular de mantenimiento.

En Europa, el control de la vegetación por medios biológicos tiene solamente posibilidades limitadas. La introducción de peces exóticos permite una cierta esperanza. Entre los métodos mecánicos, la siega motorizada, indispensanble para la explotación racional de pisciculturas bastante amplias, es grandemente utilizada y eficaz para la vegetación palustre. El control de los vegetales palustres por medio de herbicidas parece ser un método racional que gana terreno lentamente. La lucha química contra los vegetales flotantes y sumergidos ha realizado progresos efectivos estos últimos años, pero todavía quedan por resolver muchos problemas.

1 INTRODUCTION

Dans le cycle biochimique des eaux douces, la végétation aquatique constitue un maillon indispensable. Il en est de même dans les étangs exploites pour la pisciculture et où l'alimentation n'est pas exclusivement artificielle.

En principe, il n'existe pas de plante aquatique réellement néfaste pour les étangs consacrés à l'élevage des poissons, mais beaucoup de plantes deviennent nuisibles dès que leur envahissement accélère le vieillissement de l'étang, diminue la production piscicole ou rend difficile l'exploitation normale d'un étang. C'est à ce moment que le contrôle de la végétation aquatique devient nécessaire. Très souvent, ce contrôle sera un travail d'entretien normal, comme la destruction des mauvaises herbes en agriculture.

En pisciculture, la valeur des différents végétaux aquatiques est loin d'être identique. Des végétaux palustres clairsemés sont utiles dans un étang d'élevage,mais trop denses, ils sont nuisibles si ce n'est au pied des berges pour la protection de celles-ci contre l'érosion. Ils utilisent les éléments nutritifs du fond sans influencer favorablement la production piscicole, accélèrent l'atterrissement et donnent naissance à un fond riche en cellulose et peu productif. Une végétation palustre sérrée enpêche le réchauffement de l'eau et l'accès facile des poissons. Elle rend le contrôle et le gardienat plus difficiles. Si ces végétaux ont localement ou temporairement une valeur économique (fourrage ou litière pour bétail, fabrication de carton grossier, recouvrement de toits) un peuplement dense peut être souhaité, mais ceci est alors aux dépens de la pisciculture.

Parmi les végétaux flottants, ceux qui ne sont pas enracinés comme les lentilles d'eau (*Lemna*) ou qui ont des feuilles flottantes épaisses (*Nuphar luteum*, *Nymphea alba*) sont à considérer comme nuisibles. Ils empêchent la pénétration de la lumière et entravent fortement les activités biologiques d'une pièce d'eau. Les autres végétaux flottants à feuilles plus tendres sont utiles s'ils sont présents en faibles proportions et ne recouvrent pas plus de 10 pour cent environ de la surface d'eau.

Les plantes submergées doivent être considérées comme utiles. Ce sont de grands producteurs d'oxygène, elles forment un bon substratum pour la flore et la faune nutritives et donnent naissance à un fond fertile. Les envahissements denses (*Elodea* p. ex.) sont toutefois nuisibles : fond inaccessible aux poissons, relèvement du pH, fortes variations d'oxygène, réchauffement difficile de l'eau.

Les algues filamenteuses, (sauf en faibles proportions), mais plus encore les Characeae sont nuisibles dans un étang. Les algues qui constituent les couvertures biologiques sont utiles.

Dans les étangs d'élevage à température élevée, c'est le phytoplancton qui a une valeur primordiale pour la production piscicole. On cherche à augmenter son développement au détriment de tous les autres végétaux aquatiques. Il sera donc nécessaire d'éliminer en tout ou en partie la végétation ou certains végétaux aquatiques, tout en facilitant le développement du phytoplancton qui lui-même, en formant écran pour la lumière, freinera la croissance des végétaux indésirables.

Le développement de cette végétation indésirable est d'autant plus considérable que l'eau est riche en matières nutritives, que le sol est fertile et que la facilité de pénétration de la lumière est grande, comme dans les eaux claires et peu profondes.

La mort régulière des végétaux aquatiques donne lieu à une accumulation annuelle de détritus et de vase, ce qui fait évoluer l'atterrissement à un rythme accéléré. Ceci est un phénomène naturel par lequel une eau stagnante peu profonde se transforme insensiblement en marais.

2 NETTOYAGE ET DEVASEMENT DES ETANGS NEGLIGES

Le contrôle de la végétation aquatique dans des eaux envahies et négligées depuis de nombreuses années est généralement de peu d'utilité pour une amélioration suffisante. Ici, il faut procéder à l'enlèvement de l'excédent de vase, de détritus et de touffes de végétaux palustres (Carex), ce qui est toujours une opération très coûteuse.

Pareil rajeunissement d'une eau se fait au moyen de dragueurs, de draglines ou bien à la main, avec ou sans transport mécanisé, dans des étangs à sec. Si après assèchement le sol est suffisamment dur, on peut utiliser aussi le bulldozer.

Il est souvent possible d'évacuer la vase et les détritus au moyen d'un jet d'eau puissant dans des étangs préalablement vidés. La vase ainsi liquéfiée s'écoule dans une dépression de l'étang où elle est aspirée par une pompe, puis refoulée dans une dépression en dehors de l'étang ou vers un dépôt construit à l'aide de petites digues où elle se dépose. Si un travail de dévasement est exécuté convenablement, on peut obtenir une pente régulière du fond de l'étang, mais souvent l'achèvement doit se faire à la main. La vase séchée peut être employée pour l'amélioration de terrains horticoles et agricoles.

Un système similaire peut être utilisé dans des pièces d'eau non vidangées. La vase et les détritus sont détachés et hachés sous l'eau au moyen d'une hélice à rotation rapide. L'hélice est prolongée par un tuyau d'aspiration par lequel la vase et les détritus mélangés à l'eau sont évacués à l'extérieur au moyen de tuyaux flottants.

Si l'on veut conserver la profondeur, la surface et l'emplacement initiaux des eaux stagnantes, le dévasement doit se faire périodiquement. Ce travail de restauration onéreux s'impose d'autant plus rapidement que l'atterrissement naturel est grand, que l'eau est peu profonde et riche en matières nutritives et que le contrôle régulier de la végétation aquatique a été négligé.

Il n'est pas possible d'exprimer en chiffres l'atterrissement d'un étang, car ceci varie d'une eau à une autre, mais en supposant que dans un étang riche la profondeur diminue chaque année d'un centimètre, il faut bien conclure que les endroits peu profonds deviendront un marais inutilisable après quelques dizaines d'années.

On ne peut insister assez sur le nécessité d'une profondeur suffisante et sur la possibilité d'une mise à sec complète lors de la construction d'étangs. Une profondeur de 70 centimètres doit être considérée comme un minimum, sauf dans certains étangs d'élevage qui sont d'ailleurs à sec la plus grande partie de l'année et où la faible profondeur est indispensable pour l'élevage envisagé comme dans les frayères à carpes et les étangs pour jeunes brochetons.

Une profondeur suffisante freine ou rend impossible le développement des massettes (Typha), des roseaux (Phragmites communis), des glycéries (Glyceria maxima) et des laîches (Carex), car ce sont surtout ces plantes qui contribuent à un atterrissement accéléré. Une profondeur d'eau de 1,50 m résoud pour longtemps le problème d'une végétation envahissante. En Europe toutefois, la pisciculture à température élevée se pratique généralement dans des étangs assez grands et donc sur des terrains peu accidentés où il est difficile de construire des pièces d'eau profondes. En plus, une trop grande profondeur empêche le réchauffement de l'eau, mais souvent il sera plus rentable d'avoir une eau moins chaude qu'une pièce d'eau rendue inutilisable après quelques années par une végétation envahissante.

La possibilité de mise à sec réelle et totale est très importante pour un étang et surtout pour un étang d'élevage. Des mises à sec hivernales par fortes gelées ou estivales par temps sec, ont beaucoup d'avantages et influencent favorablement la décomposition de la vase, ce qui freine l'atterrissement. De meilleurs résultats sont encore obtenus si la mise à sec est accompagnée d'un travail du sol, superficiel sur terrain léger, profond sur terrain lourd. L'alternance d'un élevage de poissons et d'une culture agricole nécessitant un sarclage est certainement une des meilleures méthodes d'entretien du fond d'un étang.

3 CONTROLE DE LA VEGETATION COMME TRAVAIL D'ENTRETIEN DES ETANGS

3.1 Méthodes biologiques

Le contrôle de la végétation aquatique par une méthode biologique présente un grand intérêt en pisciculture. Malheureusement, les possibilités en Europe semblent peu nombreuses ou difficiles à réaliser. On ne possède pas de poisson herbivore indigène capable de contrôler efficacement les végétaux aquatiques.

Des biologistes européens, surtout d'Europe orientale et centrale, ont introduit et expérimenté avec un poisson de la famille des Cyprinidae et d'origine chinoise : Ctenopharyngodon idella (Scheer, 1964). Ce poisson, qu'on peut élever en étang, se nourrit presque exclusivement de végétaux supérieurs immergés mais aussi de végétaux flottants et palustres. Il consomme des quantités importantes de végétaux, il a une croissance rapide, est peu exigeant du point de vue oxygène et peut avoir une grande valeur pour la consommation. Dans son pays d'origine, il vit dans des eaux assez profondes et supporte un climat continental: étés très chauds, hivers rigoureux. Il s'y reproduit dans les rivières où les jeunes poissons sont capturés, puis élevés en étang. La température optimale pour le Ctenopharyngodon idella est de 18° à 28° C. Il est probable qu'en beaucoup de pays d'Europe, son élevage sera possible, mais la grande difficulté réside dans la reproduction. Depuis qu'il est apparu que sa maturité sexuelle peut être obtenue par l'injection d'hypophyse, les possibilités pour élever ce poisson en pisciculture ont fortement augmenté. Les essais faits jusqu'à maintenant avec ce poisson ne permettent toutefois pas encore de dire avec certitude si le Ctenopharyngodon idella sera pour la pisciculture en Europe un poisson réellement intéressant.

Un autre cyprinide d'origine chinoise, Hypophtalmichthys molitrix, est aussi herbivore, mais il se nourrit essentiellement de phytoplancton. Lui aussi a été introduit pour essais dans certains pays d'Europe orientale et centrale, mais il ne semble pas devoir jouer un rôle dans le contrôle de la végétation aquatique nuisible.

Le développement de la végétation submergée et flottante peut être entravé indirectement par le déversement d'une grande quantité de carpes de 2 ou 3 ans. En cherchant leur nourriture, ces poissons remuent le fond et rendent l'eau trouble, ce qui empêche la pénétration de la lumière et par conséquent le développement des végétations aquatiques. Par une forte mise en charge de carpes, on peut aussi obtenir la disparition de végétaux superficiellement enracinés. Dans les étangs d'alevinage pour carpes, on constate souvent un développement important d'algues filamenteuses. Si dans ces étangs, on ajoute un nombre suffisant de carpes de 1 et de 2 étés, ces algues disparaissent.

Des cygnes sur un étang peuvent contribuer au contrôle de la végétation submergée des endroits peu profonds. Les lentilles d'eau (Lemna) disparaissent si on élève sur un étang un nombre suffisant de canards qui se nourrissent volontiers de ces plantes. Aussi bien la disparition des lentilles d'eau que la fumure due aux canards augmentent la production piscicole. L'élevage systématique de carnards sur des étangs utilisés essentiellement pour la pisciculture peut être d'un rapport supplémentaire important et permet en même temps un certain contrôle de la végétation submergée. Mailick (1962) signale la disparition d'Elodea canadensis dans un étang d'un hectare sur lequel se trouvaient 12 canards.

Le ragondin (Myocastor coypus) qui ne se nourrit pas de poissons mais surtout de végétaux palustres, est élevé avec un certain succès en quelques endroits de l'Allemagne et de la Pologne dans des étangs cloisonnés. Son élevage (une quinzaine d'individus/ha) dans le but de contrôler économiquement la végétation palustre est toutefois loin d'avoir atteint le but que certains avaient espéré.

Notons ici que dans les étangs peu profonds et avec un fond suffisamment dur, le bétail peut se nourrir de jeunes végétaux palustres.

Il est quelquefois possible de contrarier le développement d'une plante nuisible par l'introduction d'une autre plante, moins nuisible ou utile. Ainsi Elodea canadensis, souvent fort envahissant, peut être supplanté après l'introduction de Callitriche. L'enracinement superficiel de cette dernière plante et sa densité moins grande permettent un contrôle plus aisé.

Dans un même ordre d'idées, on essaie souvent en pisciculture d'augmenter le développement du phytoplancton au détriment des végétaux submergés au moyen de fumure, ainsi que par la mise à sec et le travail du sol. L'application d'une fumure nécessite au préalable l'élimination de la végétation submergée, flottante et palustre. En effet, il ne faut pas que ces engrais profitent à ces végétaux. Si le plancton se développe convenablement, il forme écran à la lumière et empêche le développement ultérieur des végétaux supérieurs. Généralement, dans les piscicultures européennes, on applique d'abord de la chaux, puis on distribue des phosphates. Dans le courant de la saison de croissance, un second épandage d'engrais phosphatés a lieu.

La fumure des étangs n'a toutefois pas toujours comme conséquence un développement important de plancton, car les conditions climatiques sont aussi un facteur déterminant. En général, le développement du plancton est d'autant meilleur que le temps est stable et chaud.

Un développement important d'algues unicellulaires n'est pas non plus sans danger. Il peut se produire un relèvement anormal du pH, la pourriture des branchies (Branchiomyces) fait plus facilement son apparition et la décomposition de ces algues peut provoquer un manque d'oxygène. Bank (1962) indique l'utilisation de 150 kg de chaux vive/ha pour la floculation des algues mortes. Des indications concernant la lutte chimique contre les algues sont données plus loin dans ce texte.

3.2 Méthodes mécaniques

Dans la pisciculture européenne ce sont les méthodes mécaniques et surtout le faucardage qu'on utilise la plupart du temps pour le contrôle de la végétation envahissante.

3.2.1 Règles du faucardage

On peut dire que dans de nombreuses piscicultures, le faucardage est un travail d'entretien annuel. Bien exécuté, ce procédé est efficace contre la végétation palustre, aussi contre les végétaux enracinés et à feuilles flottantes, mais beaucoup moins pour le contrôle de la végétation submergée, qui peut redevenir rapidement envahissante. Si dans un étang les végétaux palustres sont régulièrement faucardés, le travail est considérablement allégé. Par un faucardage suffisamment tôt dans la saison, il est possible de se débarrasser de Trapa natans.

Il est indiqué de faucarder la végétation palustre au moins deux fois par an, une première fois durant le mois de mai quand la végétation est encore tendre, une seconde fois avant la floraison. Des essais sont en cours, notamment en Allemagne (Schäperclaus, 1961) afin de connaître le meilleur moment pour le faucardage des différentes espèces de végétaux, car c'est un problème qui est encore mal connu. La façon dont le faucardage est exécuté a son importance aussi. Généralement, on coupe un peu au-dessus du sol, mais il a été constaté qu'un faucardage à ras du sol était nettement plus efficace contre certaines plantes comme Sagittaria sagittifolia. Ceci n'est toutefois possible qu'avec des instruments reposant et travaillant directement sur le sol.

Il ne faut pas perdre de vue non plus que pour lutter convenablement contre les végétaux palustres, il faut garder dans l'étang un niveau d'eau le plus haut possible aussi bien avant qu'après le faucardage. L'inconvénient d'un moindre réchauffement de l'eau sera compensé par un meilleur entretien et une surface utilisable plus grande.

Une fois la végétation coupée, elle flotte à la surface. Il n'est pas indiqué de laisser dans un étang une quantité importante de végétaux coupés, car il peut en résulter un manque d'oxygène ou un milieu favorable pour le développement de la pourriture des branchies (Branchiomyces). Les tissus végétaux durcis sont riches en cellulose et de ce fait difficilement décomposables. On essaie donc d'enlever les végétaux coupés quand, par le vent, ils sont rassemblés près d'une rive. Là, on peut les composter avec de la chaux ou bien mettre les végétaux en tas dans l'étang où ils se décomposent lentement.

3.2.2 Pratique du faucardage

Les méthodes et les appareils utilisés pour le faucardage proprement dit sont nombreux et variés. Il peut s'agir d'instruments très simples ou de faucardeuses mécaniques.

Le faucardage mécanique nécessite des étangs suffisamment grands et une surface totale qui justifie la mécanisation. Les petites exploitations achètent une faucardeuse en commun ou s'adressent à des entrepreneurs de faucardage. Il faut aussi que les étangs soient dépourvus d'obstacles et que l'accès soit possible.

Dans les petits étangs, on utilise une faux à main simple ou double, manoeuvrée de la berge ou en pénétrant dans l'eau. Le faucheur est alors pourvu de longues bottes en caoutchouc. L'espace compris entre le talon et la lame de la faux ne peut être trop grand, afin d'éviter l'accrochage et l'accumulation des plantes.

On peut monter une faux double sur un pivot à l'arrière d'une barque ou jumeler deux barques ainsi équipées. Schäperclaus (1961) signale qu'ainsi 4 personnes (deux qui fauchent et deux qui font avancer les barques jumelées) peuvent faucarder 2 à 3 ha en 8 heures.

La faux articulée se compose de plusieurs lames de faux, arrondies aux extrêmités et reliées les unes aux autres au moyen de boulons ou de rivets. Cette faux repose sur le fond et deux hommes marchant dans l'eau ou sur la rive, ou bien se trouvant dans deux barques jumelées, lui donnent un mouvement de va-et-vient. La même faux peut être actionnée par un moteur se trouvant dans une barque qu'on fait avancer au moyen d'une gaffe ou par des roues à aubes.

Au lieu de faux articulés, on utilise aussi des scies spéciales sous forme de rubans et pourvues de dents des deux côtés. Elles ont une longueur de 10 à 35 m et lors de l'utilisation, on les tourne quelques fois sur elles-mêmes. Si elles sont courtes, elles doivent être alourdies par des fuseaux métalliques.

Il existe aussi un modèle de faux sous forme de V, reposant sur le sol et remorquée à l'angle par une barque. Deux ou trois barques peuvent être fixées les unes aux autres. Ces barques sont poussées avec des gaffes, ou tirées par des animaux, si le fond le permet, ou pourvues d'un moteur.

Les faucardeuses mécaniques le plus souvent utilisées dans les grandes exploitations piscicoles sont des embarcations munies à l'avant de lames ou d'autres instruments faucheurs. Ces instruments sont actionnés par un moteur qui sert aussi pour la propulsion de l'embarcation. Il existe en Europe de mombreux modèles de faucardeuses mécaniques. Certaines sont faites en série par des constructeurs, mais il y a aussi plusieurs modèles qui ne sont pas dans le commerce et spécialement adaptés aux besoins locaux. Il a été construit aussi des engins à usage multiple: fraiser, faucarder, épandre l'engrais. Schuberth (1954-1956) a décrit dans une série d'articles plusieurs faucardeuses mécaniques.

Une bonne faucardeuse doit être légère, robuste, d'un faible tirant d'eau, avec possibilité de régler la profondeur de coupe. Elle doit être facilement manoeuvrable par un seul homme et transportable sur terre ferme sans difficulté (Huet, 1960). D'après les conditions de travail, une bonne faucardeuse permet de faucher 2 à 5 hectares par jour.

La plupart du temps, les instruments faucheurs se composent de deux barres coupeuses (principe de la faucheuse agricole), une horizontale et une verticale. Cette dernière coupe la végétation trop dense qui pourrait freiner la progression de l'embarcation. La largeur de coupe varie de 2 m à 2,5 m et d'après les machines, la profondeur de coupe peut aller de 0,20 m à 1,50 m.

Schuberth (1954-1956) décrit deux autres systèmes d'éléments faucheurs placés à l'avant d'une embarcation propulsée au moyen d'un moteur. Le premier se compose de 4 scies circulaires dont 3 horizontales et une verticale. Il permet de couper une végétation très dense et très dure jusqu'à une profondeur d'un mètre. Sa capacité est de 3 à 8 ha par journée de 8 heures. L'ensemble est toutefois encombrant et lourd et d'un trop grand tirant d'eau. L'autre système se compose d'un ensemble de 3 faux en forme de V, reposant sur le sol à l'avant de l'embarcation et coupant sur une largeur de 3 mètres. Les végétaux coupés sont dégagés à l'avant au moyen de 3 spirales. Si ce modèle permet de faucarder 6 à 7 ha par jour, il ne convient toutefois que si la végétation est jeune et tendre. Le fait de remuer le fond de l'étang et de provoquer ainsi une utilisation accélérée des substances nutritives, est un avantage. Cet avantage existe aussi, mais en moindre mesure, pour tous les engins faucardeurs qui reposent sur le fond.

Pour la propulsion des bateaux faucardeurs, on utilise généralement des roues à aubes, rarement une hélice. Notons ici qu'en France (Anon. 1955) certains bateaux sont équipés d'une hélice anti-herbes. Schuberth (1960) a décrit une faucardeuse mécanique amphibie. Le système faucheur est du type classique, mais les roues à aubes sont transformées en grandes roues remplies d'air. Si la profondeur d'eau est inférieure à 30 cm, les roues avancent sur le fond, si la profondeur devient plus grande, elles flottent et fonctionnent comme des roues à aubes. Cette faucardeuse peut être utilisée dans des profondeurs d'eau qui ne dépassent pas 10 cm.

L'enlèvement des végétaux coupés est un travail fastidieux et difficile. Schäperclaus (1961) signale qu'en U.R.S.S., on utilise des faucardeuses pourvues de haches-paille qui hachent en petits morceaux les roseaux coupés. La quantité de roseaux hachés et laissés dans l'étang ne peut toutefois pas dépasser 1.500 kg à l'hectare. Schuberth (1958) décrit un appareil simple pour rassembler sur la rive les végétaux coupés flottant sur l'eau. Il s'agit d'un grand rateau en bois de 4 m de large, pourvu d'une rangée de 15 dents d'une longueur de 30 cm. Ce rateau est monté sur une embarcation légère et il est possible de régler sa profondeur de travail au moyen d'un levier. Avec un long câble, l'ensemble est tiré par un treuil se trouvant sur la rive et mû par un moteur. Des bandes d'une largeur de 4 m sont ainsi successivement nettoyées. Après chaque passage, la barque-rateau retourne de ses propres moyens pour entamer un nouveau ramassage. Deux hommes sont nécessaires pour ce travail, un au treuil, l'autre dans la barque.

Le principe de l'appareil décrit par Schuberth (1958) pour rassembler la végétation coupée peut être utilisé pour l'arrachement des végétaux. Le rateau en bois est alors remplacé par un instrument moins large reposant sur le fond: une chaîne lourde, une barre coupante, ou un rateau en fer. Si l'on travaille sur un fond pourvu d'obstacles, il faut qu'on puisse débrayer facilement le treuil et que deux hommes se trouvent dans la barque pour soulever l'instrument-arracheur. Chancellor (1958) signale l'emploi d'une chaîne lourde reposant sur le fond et tirée par deux tracteurs avançant sur les berges. Il est certain que cet engin, ainsi que celui qui vient d'être décrit, convient mieux pour l'arrachement de la végétation submergée et flottante enracinée, que pour le contrôle de la végétation palustre.

Dans certains étangs, il se forme des îles flottantes, conposées de végétaux palustres (Glyceria, Typha). On essaie de les tirer sur la berge au moyen d'un treuil, éventuellement après avoir découpé ces îles en morceaux.

3.2.3 Autres méthodes mécaniques

Certaines méthodes sont fort simples: l'enlèvement des algues filamenteuses et des lentilles d'eau (Lemna) au moyen de récipients perforés fixés à un bâton; le rassemblage des algues filamenteuses avec des filets; l'évacuation des lentilles d'eau ou des algues en les poussant vers la sortie au moyen de planchettes; l'entraînement de ces mêmes végétaux vers la sortie par un courant d'eau ou par un jet d'eau ; l'arrachement et l'enlèvement à la main des végétaux submergés et superficiellement enracinés (Callitriche) au moyen de rateaux ou de crochets attachés à une corde. Il est toutefois certain que ces méthodes ne sont utilisables que quand il s'agit de petites pièces d'eau.

Notons encore parmi les méthodes mécaniques pour contrôler la végétation aquatique envahissante, l'installation d'écrans pour empêcher l'accès de la lumière. Ces écrans sont sous forme de radeaux qu'on déplace régulièrement et qui sont couverts de planches ou d'un tissu plastique noir. Cette méthode ne peut convenir que pour des pièces d'eau de faible superficie.

Brûler les végétaux palustres en hiver ou au début du printemps quand les plantes sont bien sèches, ou les récolter sur la glace, n'influence pas leur développement ultérieur. On freine toutefois l'accumulation de matières organiques peu intéressantes, tandis que la destruction par le feu des végétaux palustres accompagne utilement la désinfection du fond d'un étang.

On peut encore inclure dans les méthodes mécaniques pour le contrôle des végétaux nuisibles, la mise à sec et le travail du sol. Une mise à sec convenable en hiver, accompagnée de fortes geleés diminue la vigueur de développement de plusieurs plantes comme Elodea canadensis, Nuphar luteum et Nymphaea alba. Une mise à sec estivale en période sèche et un travail du sol ont aussi un effet favorable pour le contrôle de la végétation envahissante.

3.3 Méthodes chimiques

En Europe, la lutte chimique contre les mauvaises herbes en agriculture s'est fort développée dans le but de rationaliser les exploitations et de pallier au manque de main - d'oeuvre qui se manifeste dans de mombreux pays. Le contrôle au moyen d'herbicides de la végétation aquatique nuisible ou en excès a retenu aussi l'attention ces dernières années pour des raisons identiques (Timmermans, 1961). L'emploi des herbicides dans le milieu aquatique, et spécialement en pisciculture, est toutefois loin de connaître le développement constaté en agriculture, mais tous les pays s'intéressent à cette méthode de contrôle relativement récente.

On peut dire que la lutte chimique contre la plupart des végétaux palustres ne pose plus beaucoup de problèmes et qu'elle commence à être utilisée par les praticiens. Il n'en est pas de même pour le contrôle de la végétation flottante et submergée qui est toujours l'objet de nombreux essais, dont certains peuvent être considérés comme réellement prometteurs et qui, de temps à autre, sont appliqués dans des exploitations piscicoles.

Le choix entre les méthodes de contrôle mécanique et chimique sera en grande partie déterminé par le prix de revient, l'efficacité et la durabilité. Il n'est pas possible actuellement de se prononcer à ce sujet: le coût de la main d'oeuvre diffère souvent fortement d'un pays à un autre, les conditions de traitement sont fort variables, les résultats obtenus et le prix des herbicides varient d'après les végétaux à contrôler. Il est toutefois certain que l'emploi des herbicides contre la végétation palustre sera très souvent plus économique que le faucardage. Il est certain aussi que le contrôle chimique, aussi bien que le contrôle mécanique, seront toujours à considérer comme un travail d'entretien généralement d'autant plus facile qu'il sera plus régulier.

La lutte chimique contre la végétation aquatique en pisciculture pose de plus nombreux problèmes que le faucardage qui est une technique relativement simple. Souvent on se trouve devant une végétation fort variée dont le contrôle nécessite des herbicides différents, ce qui complique l'application. Leur toxicité pour les poissons, pour la faune nutritive (Bauer, 1961), le bétail, les terres irriguées et les cultures avoisinantes nécessite une attention constante et des connaissances accrues. Le manque d'uniformité dans les études toxicologiques et les différentes compositions commerciales des herbicides ne permettent pas toujours d'apprécier de façon suffisante la toxicité réelle. Les connaissances biologiques sur les effets de l'utilisation répétée des herbicides ne sont pas fort avancées.

Ces problèmes et difficultés ne sont toutefois pas spécifiques au domaine de la pisciculture qui, comme l'agriculture, cherche dans les herbicides un moyen de rationalisation. Certains herbicides très toxiques ou dangereux, comme les benzènes chlorés, l'acroléine, l'arsénite de soude ou le chlore ne sont pas à utiliser. En plus, la destruction complète de la végétation n'est pas toujours nécessaire ni souhaitée. Il faudra toutefois qu'en pisciculture les herbicides ne soient utilisés que par des personnes compétentes suffisamment averties. Une standardisation des méthodes toxicologiques et de la présentation des résultats serait très utile. Les études concernant les effets à long terme de l'utilisation répétée des herbicides en milieu aquatique devront être continuées et approfondies.

3.3.1 Végétation palustre

3.3.1.1 Traitement des feuilles

La meilleure époque de traitement se situe de la mi-juillet à la mi-septembre, de préférence par beau temps ou en tout cas par temps sans danger de pluie durant les premières heures qui suivent le traitement. Une répartition aussi régulière que possible du produit herbicide est nécessaire, ainsi qu'un jet puissant si la végétation est dense et haute. L'emploi d'un "jet-miroir" est à conseiller. La quantité de solution varie d'au moins 100 l/ha pour les appareils à volume réduit (nébulisateurs) à 1.000 l et plus pour les pulvérisations ordinaires. Elle dépend aussi de la densité de la végétation et des difficultés de progression. L'emploi d'un volume réduit (gouttelettes très fines) ne peut se faire qu'en absence de vent et quand le degré hygrométrique de l'air est élevé.

Les appareils utilisés sont ceux qu'on emploie en agriculture, adaptés ou non aux conditions spéciales du traitement. Ils sont portés à dos ou transportés dans une barque. S'il s'agit d'appareils puissants, on peut les laisser sur la berge et faire le traitement au moyen de longs tuyaux. Il existe des engins ou barques spécialement outillés pour le traitement des végétaux aquatiques, mais ce sont toujours des prototypes.

Contre Phragmites communis, on utilise les produits suivants qui permettent généralement un contrôle efficace durant plusieurs années:

amitrol: 10-15 kg de matière active/ha
amitrol-(T): 8-12 kg de matière active/ha
dalapon: 20-25 kg de matière active/ha
dichlorobutyrate de sodium: 20-25 kg de matière active/ha
dalapon + amitrol: 15 + 5 kg de matière active/ha
dalapon + amitrol- (T): 15 + 3 kg de matière active/ha

Les herbicides indiqués comme efficaces contre Phragmites communis le sont aussi contre Typha latifolia, Typha angustifolia, Glyceria maxima, Glyceria fluitans (après abaissement du niveau d'eau) Phalaris arundinacea.

Carex sp. Juncus sp., Acorus calamus, Iris pseudacorus et Scirpus lacustris sont des plantes plus résistantes pour lesquelles des doses plus grandes sont souvent nécessaires.

Le mélange de dalapon et amitrol ainsi que de dalapon et amitrol-(T) est souvent considéré comme des plus efficaces. Amitrol et amitrol-(T) permettent de contrôler en même temps des végétaux aquatiques à feuilles larges.

Juncus sp. peut aussi être contrôlé avec le 2,4-D et le MCPA (3 à 4 kg de m.a./ha), de même que Stratiotes aloides.

Contre Sparganium ramosum, Sagittaria sagittifolia et Alisma plantago, on utilise le 2,4-D ou le 2,4,5-T (3 à 5 kg de m.a./ha).

Equisetum limosum et Equisetum palustre sont deux plantes très difficiles à détruire au moyen d'herbicides et il est souvent nécessaire de répéter les applications. On utilise: 2,4-D, 2,4,5-T, MCPA ou MCPB (4 à 5 kg de m.a./ha); amitrol (10 à 15 kg de m.a./ha); amitrol-(T) (8 à 12 kg de m.a./ha).

Certains végétaux palustres : Juncus sp. , Sparganium ramosum, Sagittaria sagittifolia, sont fort sensibles aux herbicides à base de dipyridylium, le paraquat et le diquat (3 à 4 kg de m.a./ha). On peut d'ailleurs utiliser ces mêmes produits contre la plupart des végétaux palustres, mais les résultats sont moins complets et moins durables qu'avec les herbicides précédents et on peut considérer l'effet comme un fauchage partiel chimique.

Dans le commerce, on trouve de nombreux mélanges d'herbicides dont le but est de contrôler une gamme plus large de végétaux: amitrol + 2,4-D + simazine; dalapon + 2,4-D + MCPA; diuron + amitrol ; TCA + amitrol + 2,4-D, etc. Ces mélanges peuvent convenir aussi pour le contrôle de la végétation palustre.

3.3.1.2 Traitement du fond

Pour lutter contre les végétaux palustres, on peut traiter aussi le fond des étangs à sec, si possible après fauchage et évacuation des végétaux coupés. On utilise: chlorate de soude (300 kg de m.a./ha); TCA (120 à 160 kg de m.a. /ha); monuron (30 kg de m.a./ha); diuron (25 kg de m.a./ha); CMU (20 kg de m.a./ha). Souvent des quantités plus importantes de ces produits sont nécessaires, surtout si le fond de l'étang est vaseux. En général, l'efficacité de ces traitements est nettement moins bonne que celle d'herbicides pulvérisés sur le feuillage et les résultats sont d'autant moins bons que le fond est riche en matières organiques. On peut aussi traiter le fond des étangs nouvellement creusés afin d'empêcher temporairement l'installation d'une végétation palustre. Sont utilisés alors des produits qui restent longtemps actifs dans le sol, comme le CMU.

Les herbicides cités, aussi bien ceux à pulvériser sur les feuilles que ceux destinés au traitement du fond sont sans danger pour les poissons, s'ils sont utilisés aux doses indiquées et de façon normale, c'est-à-dire pulvérisés sur le feuillage si l'on traite les plantes directement et pour une profondeur d'eau d'au moins 50 cm si, après le traitement du fond d'un étang à sec, on met sous eau et on rempoissonne immédiatement.

3.3.2 Végétation flottante

La lutte chimique contre la végétation flottante est moins facile que celle contre les végétaux palustres. Son utilisation dans les piscicultures d'Europe est d'ailleurs encore rare.

En traitant les végétaux flottants au moyen d'herbicides, il faut éviter que les produits utilisés soient lavés des feuilles par le mouvement de l'eau. Ceci est surtout le cas si l'on utilise une barque, ce qui est souvent nécessaire. L'adjonction d'un adhésif est indiqué et, si cela est possible, l'emploi d'un nébulisateur qui permet de traiter à plus grande distance. On essaie aussi de baisser temporairement le niveau de l'eau, surtout si l'on utilise les phytohormones. Dans ce cas, il faudra attendre au moins 5 à 6 heures avant de remettre sous eau de nouveau.

Nuphar luteum, Nymphaea alba, Limnanthemum nymphaeoides et Hydrocharis Morsus ranae sont convenablement contrôlés par des produits à base d'esters de 2,4-D et de 2,4,5-T ou par un mélange de ces deux produits (2 à 4 kg de m.a./ha). A cause de leur grande volatilité ces esters sont toutefois des herbicides à utiliser avec une grande prudence, et il est recommandé de ne pas employer un nébulisateur, ni de faire l'application par vent trop fort. En plus, ils sont généralement plus toxiques que les autres phytohormones. Pratiquement toutefois, il n'y a pas de danger pour la faune piscicole si le traitement est fait de façon normale, c'est-à-dire si le produit n'est pas complètement lavé des feuilles dans des pièces d'eau dont la profondeur est inférieure à 50 cm.

Contre les plantes flottantes précitées, on peut utiliser aussi d'autres formes à base de 2,4-D et de 2,4,5-T ainsi que du MCPA ou du MCPB (3 à 5 kg de m.a./ha). Ces produits conviennent aussi pour le contrôle des Lemnaceae, mais l'application est difficile.

Hydrocharis Morsus ranae est très sensible au diquat et au paraquat ou à un mélange des deux (1 à 2 kg de m.a./ha), tandis que Potamogeton natans et Ranunculus aquatilis peuvent être contrôlés durant une saison de croissance avec les mêmes produits. Ces herbicides détruisent aussi les Lemnaceae dans les étangs sous eau, mais il faut que la pulvérisation soit faite soigneusement afin d'atteindre toutes les plantes et que la couche de Lemnaceae ne soit pas trop épaisse, ce qui nécessite alors la répétitition du traitement. En ce qui concerne l'emploi du diquat et du paraquat, des indications complémentaires sont données dans la partie qui traite du contrôle de la végétation submergée.

Trapa natans est contrôlé avec le sel de sodium de 2,4-D (1,5 à 2,5 kg de m.a/ha). Polygonum ampnibium est une plante très difficile à contrôler et contre laquelle les phytohormones et les herbicides à base de dipyridylium ne donnent généralement que des résultats fort partiels.

La destruction des Lemnaceae peut aussi être obtenue par un épandage soigneux en hiver de cyanamide calcique (400 à 500 kg/ha) sur le fond des étangs à sec qu'on laisse ainsi durant 3 à 4 semaines.

Les herbicides qu'on utilise pour traiter le fond des étangs à sec et dont il a été question pour les végétaux palustres sont utilisés aussi contre la végétation flottante.

Il est probable que l'emploi de simazine sur le fond des étangs à sec, comme il sera indiqué dans la partie qui traite des végétaux submergés, est aussi efficace contres certains végétaux flottants.

3.3.3 Végétation submergée

En Europe, la lutte chimique contre les plantes supérieures submergées en est toujours au stade des expériences et des applications à petite échelle. On utilise les herbicides, soit en traitant le volume d'eau des étangs, soit en traitant le fond des étangs à sec.

Pour le traitement du volume d'eau des étangs, peu de produits sont utilisables, car en plus de l'efficacité contre les végétaux, la toxicité pour les poissons joue un rôle prépondérant.

L'arsénite de soude n'est pratiquement pas utilisé en Europe comme herbicide dans le milieu aquatique, le sulfate de cuivre n'est employé que pour le contrôle des algues et les granulés à base de phytohormones où l'épandage de simazine dans les étangs sous eau n'ont donné que rarement des résultats satisfaisants. Il en est de même pour l'emploi de phytohormones après abaissement du niveau d'eau de façon à mettre à sec une partie de la végétation normalement submergée.

Dans le milieu aquatique et piscicole, de bons résultats sont souvent obtenus avec les herbicides du dipyridylium: paraquat et diquat. Ils sont utilisés dans les étangs sous eau et empoissonnés et permettent souvent de contrôler une gamme assez large de végétaux submergés durant une saison de croissance et de diminuer l'envahissement durant la saison suivante. Le diquat donne généralement un résultat plus rapide que le paraguat, qui semble avoir une action plus profonde. L'action spécifique des deux herbicides n'est pas encore bien connue et en pratique on conseille un mélange de deux produits: 1 kg + 1 kg de m.a./ha, soit 5 l + 5 l des produits commerciaux.

Elodea canadensis, *Potamogeton crispus*, *Pot. pectinatus*, *Pot. oppositifolius*, *Ranunculus circinatus*, *Ceratophyllum* sp., *Myriophyllum* sp., *Chara* sp. sont sensibles au diquat et au paraquat. Les résultats contre *Potamogeton lucens* sont moins bons et les effets sur *Hottonia palustris*, *Callitriche* et la plupart des algues filamenteuses semblent faibles, sinon nuls.

Il est préférable d'utiliser les herbicides au dipyridylium avant l'envahissement complet des pièces d'eau, et il est important que leur répartition soit faite soigneusement afin d'atteindre toutes les plantes à contrôler. Si la masse des végétaux est trop compacte, la pénétration de l'herbicide est insuffisante. Il n'est donc pas nécessaire d'abaisser le niveau de l'eau avant le traitement, mais il faut qu'il n'y ait pas de matières organiques en suspension car elles inactivent rapidement les herbicides. Un traitement par temps couvert ou sombre est à conseiller. La faible toxicité de ces produits et le fait que leur destruction dans l'eau se fait assez rapidement sont un avantage. Le prix d'achat est toutefois assez élevé.

Neururer et Slanina (1960) indiquent qu'une concentration de 18 mg/l d'un produit commercial à base de TCA (30 pour cent de m.a.), amitrol (30 pour cent de m.a.) et 2,4-D (8 pour cent de m.a.) contrôle en grande partie *Myriophyllum verticillatum* sans nuire aux poissons ni à la nutrition.

Comme traitement de fond des étangs dans la lutte contre la végétation submergée, Keiz (1964) signale une expérience très réussie avec la simazine. Le traitement en hiver ou au printemps du fond bien asséché avec un produit granulé à base de simazine (10 kg de m.a/ha) a empêché le développement de la végétation submergée et flottante durant une saison de croissance. La remise sous eau au printemps se fait très lentement afin d'obtenir une forte concentration d'herbicide qui tue les racines. Il est nécessaire que le fond de l'étang ne soit pas alcalin (attendre la neutralisation après un chaulage éventuel et que le renouvellement d'eau durant la saison de croissance soit aussi faible que possible. Dans les étangs ainsi traités, les algues unicellulaires se sont convenablement développées et la production piscicole était supérieure à celle des étangs témoins. Ce traitement dont le coût est toutefois élevé, serait aussi efficace contre les *Characeae*.

Contre *Elodea canadensis*, on peut épandre aussi 750 kg de cyanamide calcique/ha, après quoi, on fait monter le niveau d'eau de 20 à 25 cm. La remise sous eau pour le rempoissonnement ne peut se faire qu'après évacuation de cette eau. Contre la même plante, Bank (1958) signale l'emploi d'azote ammoniacal (250 kg d'azote par ha). D'après le même auteur, *Fontinalis* est contrôlé par l'épandage au printemps dans l'étang à sec, de sulfate d'ammoniaque (250 kg d'azote par ha).

Pour le traitement du fond des étangs à sec, on utilise aussi d'autres herbicides totaux qui tuent les racines comme il a été indiqué pour les végétaux palustres. L'efficacité dépend en grande partie de la nature du fond et sera généralement d'autant moins bonne que le sol est vaseux et mal drainé.

3.3.4 Algues

Dans les étangs sous eau, le sulfate de cuivre est un algicide efficace et bon marché qui contrôle *Spirogyra*, *Cladophora*, *Chara* et d'autres algues. Les concentrations nécessaires sont 0,5 à 1,0 gr de sulfate de cuivre par m3 d'eau en eau acide et 1,5 à 2,0 gr en eau alcaline. Comme ces concentrations sont proches des concentrations toxiques pour les poissons, on ne traite pas l'entièreté d'une pièce d'eau, mais une partie seulement, la moitié ou le tiers par exemple. Il est nécessaire de mesurer convenablement le volume de l'eau et de répartir régulièrement le sulfate de cuivre, soit sous forme d'une solution, soit sous forme de cristaux traînés derrière une barque dans un sac à mailles larges. Chara est sensible aussi au diquat: 1 à 2 kg de m.a./ha, soit 5 à 10 l du produit commercial, d'après l'importance de l'envahissement.

C. Krause et D. Nehring (1965) signalent la destruction d'une algue bleue, Aphanizomenon, par l'épandage sur un huitième de la surface de l'eau, de 2 kg de $CuSO^4$ par ha. Grâce au vent, le sulfate de cuivre se répartit dans toute la pièce d'eau. Les auteurs indiquent aussi l'avantage du sulfate de cuivre contre la pourriture des branchies (Branchiomyces) si l'application est faite au début de l'apparition de cette maladie. Ils n'ont pas pu déceler une accumulation de cuivre dans des étangs traités plusieurs fois au $CuSO^4$.

Contre les algues unicellulaires, on conseille l'emploi de 8 à 12 kg de $CuSO^4$/ha, appliqué au cours de l'été en 4 doses de 2 à 3 kg.

L'efficacité du sulfate de cuivre est d'autant meilleure que la température de l'eau est élevée et de préférence pas inférieure à 16°C. Dans les eaux riches, bien exposées au soleil, le contrôle des algues n'est pas toujours durable et, sauf pour les Characeae, une répétition du traitement peut être nécessaire après 2 mois.

Contre les algues filamenteuses en étangs empoisonnés, Bank (1962) signale l'emploi d'oxychlorure de cuivre (1 kg de Cu/ha), de vert de malachite (0,3 gr/m3), d'un fongicide à base d'un dérivé de l'acide dithiocarbamique (2,5 kg de m.a./ha) ou l'épandage sur les algues de superphosphate moulu du commerce avec 16% d'acide phosphorique (600 kg/ha). Tous ces produits sont très probablement moins efficaces que le sulfate de cuivre et ne contrôlent pas les Characeae. Ils sont toutefois plus sûrs en ce qui concerne la toxicité pour les poissons.

Einsele (1964) utilise dans les étangs à truites de la chaux vive moulue pour la destruction des flocons d'algues à la surface de l'eau. Le but est d'atteindre un pH de 10,0 à 10,2 pendant un temps très court. Cette méthode semble toutefois dangereuse et difficile à réaliser dans de grands étangs à faible débit d'eau.

Pour le contrôle des algues filamenteuses et unicellulaires dans les étangs empoissonnés, on utilise aussi les produits suivants: monuron (1-2 ppm), CMU (1-2 ppm) diuron (0,5-1,0 ppm), le dichloronaphtoquinone (0,05-0,15 ppm0).

D'après Keiz (1964), l'épandage de simazine (10 kg de m.a./ha) sur le fond des étangs à sec pour le contrôle de la végétation submergée empêche le développement des Characea et des algues filamenteuses.

Bank (1958) signale la destruction des algues filamenteuses encore fraîches sur le fond des étangs asséchés par l'épandage de sulfate d'ammoniaque (au moins 60 kg d'azote par ha).

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AQUATIC WEED CONTROL IN FISH PONDS

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Abstract

Results of 30 years of aquatic weed control research in fish ponds at this Station are summarized. This summary includes a listing of important algae genera and aquatic weed species, and information on pond construction features of significance in aquatic weed control, as well as mechanical, biological, and chemical control techniques. Included in discussions on chemical control techniques are data on fish toxicity of each herbicide as well as effective rates of application for use under pond conditions.

LUTTE CONTRE LA VEGETATION AQUATIQUE DANS LES ETANGS DE PISCICULTURE

Résumé

Ce document fait le point des résultats de trente années de recherche sur la lutte contre la végétation aquatique dans les étangs de pisciculture de cette station expérimentale. Il contient une liste des principales algues et plantes aquatiques ainsi que des renseignements sur les caractéristiques de construction des étangs revêtant une importance pour le contrôle de la végétation aquatique ainsi que sur les procédés mécaniques, biologiques et chimiques de lutte contre cette végétation.

L'examen des moyens de lutte chimique comporte des données sur la toxicité des divers herbicides à l'égard du poisson ainsi que sur les doses pratiques recommandées dans les conditions de pisciculture en étang.

LUCHA CONTRA LAS MALAS HIERBAS ACUATICAS EN LOS ESTANQUES PISCICOLAS

Extracto

Se resumen los resultados de 30 años de investigaciones en esta Estación, en la lucha contra las hierbas adventicias acuáticas en los estanques piscícolas. Este resumen comprende una lista de importantes géneros de algas y especies de plantas adventicias acuáticas, así como información sobre características de la construcción de estanques de importancia para la lucha contra las hierbas adventicias acuáticas, así como las técnicas de lucha mecánica, biológica y química. Junto con las discusiones sobre las técnicas de lucha química figuran datos sobre toxicidad para los peces de cada uno de los herbicidas, así como las cantidades efectivas en que han de aplicarse, para su utilización en las condiciones de los estanques.

1 INTRODUCTION

Weed infestations vary in different types of fish ponds. In a new pond, weeds will usually appear during the first year or two if the pond is not fertilized. If water is clear, within a few months weeds will fill major portions of the pond. If water is muddy most of the time, there will be limited weed growth except in shallower, marginal areas. Swingle (1945), reported total fish production was practically the same in weed-filled and muddy ponds, but the catch of fish was greater in muddy ponds since weeds were not present to interfere with angling.

Ponds with fluctuating water levels, even though fertilized, often become partially or completely filled with weeds. During summer months, when the water level recedes, weeds invade the wet, exposed pond edge. When the water level returns to normal, as a result of winter rains, many species of these weeds continue to grow and begin their invasion of deeper waters.

Hatchery ponds are excellent habitats for all kinds of aquatic weeds since they are drained one or more times during warm months of each year. Even though these ponds are immediately refilled with water the bottoms are exposed to sunlight for several weeks because of difficulty in obtaining a phytoplankton growth in newly-filled ponds. This clear water period gives the weeds an excellent opportunity to become established.

2 AQUATIC WEED IDENTIFICATION

Aquatic weeds can be defined as those unwanted and undesirable plants growing in an aquatic environment and refer only to those plants which are adapted to grow and reproduce under such aquatic conditions. A knowledge of the identity of several hundred species of aquatic plants, which interfere with fish pond operations, is necessary if efficient and effective chemical control practices are to be employed. As an aid in both identification and use of control measures the following simple outline of major plant groups based upon their shape, size, and growth habits has been developed.

Algae
  Planktonic (e.g. Microcystis, Anabaena)
  Filamentous (e.g. Spirogyra, Pithophora, Chara, Nitella)
Submerged weeds (e.g. Potamogeton, Elodea, Ceratophyllum, Utricularia)
Emersed weeds (e.g. Nymphaea, Hydrocotyle)
Marginal weeds (e.g. Juncus, Typha, Carex, Sarpus, Sparganium, grasses)
Floating weeds (e.g. Pistia, Eichhornia, Trapa, Lemna, Salvinia, Azolla)

3 PREVENTION OF WEED GROWTHS IN NEW PONDS

The simplest and easiest method for control of aquatic weeds is to prevent their establishment in a pond. Proper construction of the pond is a major step in this type of control. Before construction is started, the proposed pond site should be checked to determine that it meets the requirements for a good pond as described by Lawrence (1949). Construction features include: (i) a dam sufficiently high to produce an impoundment with a minimum of water not less than 0.5 m in depth; (ii) deepening of the pond edge to reduce the hazard of marginal and shallow water weed growth; (iii) shaping and sodding of the pond edge above water level to reduce the area where marginal weeds could appear; (iv) a diversion ditch, if necessary, to carry excessive and/or muddy water around the pond, thus permitting fertilization of the pond from early spring until fall.

After a pond is properly located, constructed, and filled with water, the next step in prevention of aquatic weed growth is proper fertilization of the impounded water. If the pond water clears periodically, because of irregular fertilization or too large an inflow of water, sufficient sunlight often reaches the bottom for submerged weed growth to start. Therefore, it is necessary that regular fertilization of the pond, as recommended by Swingle and Smith (1942) be practised. A platform method for applying fertilizer, described by Lawrence (1952), is more efficient than the old broadcast method in that less labour is required in applying it plus the fact that plant nutrients dissolve in the top waters before they come into contact with the soil. Thus, there is a reduced likelihood of phosphorus and potash being bound on to clay particles in the bottom muds before phytoplankton can utilize them.

A pond that is properly constructed and fertilized supports a minimum of aquatic weed growth. The few weeds that appear along the pond edge must be removed immediately. Protection from aquatic weed invasion exists only as long as the preventative practices described above are kept in operation.

4 CONTROL TECHNIQUES

Since the establishment of the Farm Ponds Project on the Alabama Agricultural Experiment Station in the early 1930s research has been in progress to find means of eliminating unwanted aquatic plant growths in ponds without interfering with fish production. Techniques which have been tried and results that have been obtained are briefly outlined below. For simplicity, these techniques will be separated and classified as biological, mechanical, or chemical methods.

4.1 Biological methods

4.1.1 Inorganic fertilization

Application of inorganic fertilizer during winter months promoted growths of filamentous algae over masses of rooted aquatic weeds and resulted in the elimination of many species of submerged weeds when the weather became hot in the spring. Fish production in such treated ponds was of an explosive nature. Elimination of weed cover allowed bass to eat small bluegills and the released pressure on bluegill food supply, plus additional food produced by decomposing plants, resulted in tremendous growth of fish. This method cannot be used in ponds receiving large amounts of flood water or those with muddy water during late winter or early spring months (Swingle and Smith, 1947).

Applications of inorganic fertilizer to weed-free ponds during warm months has promoted growths of planktonic algae resulting in sufficient shading to prevent establishment of submersed and emersed species of weeds.

4.1.2 Fish

Carp: common carp (Cyprinus carpio) in sufficient numbers (400 per ha or more) roiled the bottom muds and the resulting muddy waters prevented submersed aquatic weed growth by shading.

The Israeli strain of common carp in limited numbers (55 per ha) has controlled the branched alga Pithophora and mono-filament algae in ponds.

Tilapia: T. mossambica and T. nilotica in sufficient numbers have controlled Pithophora and other filamentous algae in ponds during the warmer months.

Tilapia melanopleura in sufficient numbers have controlled filamentous algae and a number of submersed weeds in ponds during the warm months.

Grass carp (Ctenopharyngodon idella): In limited trials this species has eliminated filamentous algae, submersed and emersed weeds in small pools, (Avault, 1965).

4.2 Mechanical methods

4.2.1 Cutting

Emersed type weeds and some submersed species have been controlled by periodic cuttings plus regular fertilization. Normally two years of cutting were necessary to completely eliminate the emersed species. If fertilization was not practised during this two-year cutting period, the emersed weeds were replaced by submersed species. Thus, any cutting operation had to include an adequate fertilization program to be successful.

4.2.2 Deepening of pond edge

In old fertilized ponds repeated removal of marginal weeds including the soil (by shovel, hoe or mechanical digger) in the shallow water gradually deepened the marginal water areas and prevented weed reinfestation by elimination of suitable habitat. Thus, a deepened pond edge (no water less than 0.5 m in depth) was recommended as a construction feature for all ponds.

4.2.3 Beating

Several mono-filament forms of filamentous algae have been eliminated from fertilized ponds by beating with a cane pole or agitation of the floating algae masses.

4.2.4 Shading

Dyes: Partial control of filamentous algae and submersed weeds have been obtained by shading with dyes in the early spring. However, the dyes used (nigrosine and pontamine green) were unstable in pond waters and the colour faded rapidly. Thus, the shading effect was temporary, and repeated (weekly) applications of dyes had to be made to maintain the desired shading effects.

The floating box and submersed bag technique for applying chemicals to the surface of a pond were a result of this research with dyeing pond waters.

Silt: Submersed and emersed weeds have been eliminated from ponds in which the water periodically was muddy. Such muddy water shaded the pond bottom and deposited silt on leaves and stems of plants which aided in their control.

4.2.5 Light requirements of plants

Laboratory studies have produced some information on shading effects produced by fertilization, dyes, and silt. Brazilian elodea (Elodea densa) had low light intensity requirements (optimum growth at 10 foot-candles), and was killed by exposure to intensities greater than 200 foot-candles. Waterstargrass (Heteranthera dubia) had high light intensity requirements (optimum growth above 600 foot-candles), and was retarded by exposure to intensities less than 50 foot-candles. With each species more vigorous growth was obtained by exposure to the red end of the spectrum and less vigorous growth was produced by exposure to the blue end of the spectrum (Blackburn, 1961).

In the laboratory Pithophora, southern naiad, (Najas quadalupensis) water-thread pondweed (Potamogeton diversifolius) Brazilian elodea, and waterstargrass were successfully grown in 4-litre glass jars under light intensity of 60 to 100 foot-candles for a duration of ten hours per day.

Under slightly different laboratory conditions Pithophora, waterstargrass, common duckweed (Lemna minor), alligatorweed (Alternanthera philoxeroides) and waterhyacinth (Eichhornia crassipes) were successfully grown in 4-litre glass jars at light intensity of 600 to 800 foot-candles for a duration of 14 hours per day (Lawrence, 1964b).

Laboratory tests demonstrated that a short exposure (five to ten minutes) to a sufficent intensity of ultra violet light (2,537 A°) would cause death of duckweed.

4.3 Chemical methods

The techniques presented under this section are those developed or tried at this Station and do not imply that the same results would be obtained by the same concentrations of a given chemical on the same or other plant species in different areas of the world, or in the same areas with different soil, water, or climatic conditions (Lawrence, 1962 and in press).

4.3.1 Copper sulphate

Toxicity to fish

Formulation	Concentration in ppm safe to		
	Bass[1]	Bluegill[2]	Fathead[3]
Fine crystals	1 to 3	1 to 3	1
Application range: 0.1 to 1.0 ppm			

[1] Bass - Micropterus salmoides
[2] Bluegill - Lepomis macrochirus
[3] Fathead - Promelas pimephales

Periodic treatments at 10 to 14 day intervals at rates of 0.7 to 1.0 kg per surface ha and applied to the surface layer of water have effectively controlled the abundance of most blue-green algae (primarily Microcystis and Anabaena). Minimum rates of application were used to prevent too rapid and too extensive kills of these algae and subsequent death of fish from oxygen depletion because of plant decomposition.

Applications of 1 ppm or more have been fairly effective in controlling Chara. However, in certain waters 1 ppm has been toxic to fish.

Applications of 1 ppm have been unpredictable in their effectiveness as an algicide for the filamentous algae Oedogonium spp., Zygnema spp., Hydrodictyon spp., and Rhizoclonium spp.

Concentrations of copper sulphate that can be tolerated by fish have been ineffective as an algicide for Pithophora spp.

4.3.2 Sodium arsenite

Toxicity to fish

Formulation	Concentrations in ppm safe to		
	Bluegill	Bass	Fathead
Salt	18	12	8

Application range: 2 to 4 ppm As_2O_3

The concentrations indicated have provided excellent control of many branched, net and monofilament algae species as well as for most submersed weed species. Reliable results have been obtained over a wide range of pond conditions.

Concentrations in excess of those indicated have been ineffective on Chara spp., Nitella spp., slender spikerush, needle rush (Juncus roemericanus), and southern watergrass.

Herbicidal activity of sodium arsenite on the filamentous algae *Hydrodictyon* and *Pithophora* has been variable depending upon the stage of growth when chemical was applied.

Concentrations greater than 4 ppm As_2O_3 have reduced warm-water fish production in treated ponds.

Arsenic was found to accumulate in plankton and in bottom muds. Its accumulation was apparently due to replacement of large amounts of phosphorus by arsenic in both the plankton and muds of treated ponds (Lawrence, 1958). Arsenic concentrations in bottom muds were reduced by repeated draining and refilling of ponds.

Fish living in arsenic-treated water accumulated arsenic in scales, fins and in liver tissue, but did not accumulate it in muscular and connective tissue (Dupree, 1960).

4.3.3 2,4-D — 2,4-Dichlorophenoxyacetic acid

2,4-D	BE	-do-	butyl ester
-do-	ME	-do-	methyl ester
-do-	IPE	-do-	isopropyl ester
-do-	ICE	-do-	isooctyl ester
-do-	BEE	-do-	butoxy ethanol ester
-do-	EE	-do-	ethyl ester
-do-	PGBEE	-do-	propylene glycol butyl ether ester
-do-	ACA	-do-	acetamide
-do-	AA	-do-	alkanolamine
-do-	DMA	-do-	dimethylamine
-do-	Dacamine	-do-	duomeen-o-amine
-do-	Emulsamine	-do-	oil soluble amine

Toxicity to fish

Formulation	Concentration in ppm safe to			
	Bass	Bluegill	Fathead	Trout[1]
Acid	10	10	10	10
Na salt	400	200		112
NH_4	400	100		
AA		4		
IPE	1	1	1	
BE	2.5	2.5		
PGBEE	2	2	2	

Application range: 4.5 to 22 kg per ha

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[1] Rainbow trout - *Salmo gairdneri*

The lower rate has provided effective control of emergent and marginal weeds by repeated spraying with an ester formulation in diesel fuel as carrier (Snow, 1949).

Selective control of certain broadleafed emergent and marginal weeds has been obtained by spraying with ester or amine formulation in water carrier. With most species much more effective control has been obtained when 0.25 percent of a good emulsifying agent was added to the 2,4-D solutions.

Many submerged weeds have been controlled by applications of impregnated granules of either 2,4-D ester or amine at the maximum rate indicated.

Growths of slender spikerush (needlerush) and southern water-grass have been successfully controlled in ponds by draining, removing the rank growth, and allowing the weed to start regrowth on the empty pond bottom. This regrowth was then sprayed with an ester formulation in diesel fuel as carrier, and resprayed within one week to control plants missed by the first application. The pond bottom was then flooded.

All formulations have been ineffective as control agents for Pithophora spp. as well as for most other forms of algae.

2,4D acid was found to be rather non-toxic to fish (no kills of warm-water species at 10 ppm). The butyl ester was non-toxic to these same species at 2.5 ppm whereas the propylene glycol butyl ether ester was non-toxic at 2.0 ppm. Solvents and emulsifiers used with the various ester formulations of 2,4-D varied in toxicity to warm-water species of fish, but minimum toxic concentrations were in the range of 5 ppm or less.

4.3.4 Silvex - - - - - 2(2,4,5-trichloeophenoxy) propionic acid

-do- ,BEE	butoxy ethanol ester
-do- ,PGBEE	propylene glycol butyl ether ester
-do- ,K	potassium salt

Toxicity to fish

Formulation	Concentration in ppm safe to Bass	Bluegill	Fatheads
Acid	10	10	10
BEE	2	2	2
PGBEE	2	2	2
K	10	10	10

Application range: 4.5 to 22 kg per ha; 1 to 5 ppm

Lower rates have provided control of several hard-to-kill emersed and marginal weeds by spray application of an ester formulation in diesel fuel or water solution. The addition of 0.25 percent of a good emulsifying agent has increased the effectiveness of both spray solution combinations.

At concentrations of 2 to 5 ppm, ester formulation in water has provided excellent control of most sumbersed and emersed weeds in ponds, and has provided sufficient soil residual to prevent reinfestation for periods up to three years. The same results have been obtained using maximum rates of an ester formulation impregnated onto clay granules.

All formulations, even at maximum rates, have been ineffective as control agents for Pithophora spp., Chara spp., and most other forms of filamentous algae.

4.3.5 2,4,5-T—2,4,5,-trichlorophenoxyacetic acid

-do-	BEE	-do-	butoxy ethanol ester
-do-	PGBEE	-do-	propylene glycol butyl ether ester

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Toxicity to fish

Formulation	Concentration in ppm safe to Bass	Bluegill	Fatheads
Acid	10	10	10
BEE	2	2	2
PGBEE	3	3	3

Application range: 4.5 to 9 kg per ha

Primarily effective as a control agent for woody marginal species of plants, best results have been obtained by spraying an ester formulation in a diesel fuel carrier with 0.25 percent of an emulsifying agent added.

It is ineffective as a control agent for most emersed and submersed weeds and algae in ponds, even at the maximum rate.

4.3.6 MCP_2-methyl - 4- chlorophenoxyacetic acid

-do- AA -do- Alkylamine salt

Formulation	Concentration in ppm safe to Bass	Bluegill	Fatheads
Acid	10	10	10
AA	710	710	710

Application range: 4.5 to 22 kg per ha

Specified rates provided adequate control of marginal and floating weeds by spray application of ester formulation in diesel fuel as carrier. All chlorophenoxyacetic compounds (2,4-D; silvex; 2,4,5-T; MCP) are volatile, the ester formulation being more volatile than the amines. So, due care has to be exercised in spraying these chemicals to avoid damage to desirable surrounding vegetation.

4.3.7 Dichlone 2,3 dichloro-4-naphthoquinone

Formulation	Concentration in ppm safe to Bass	Bluegill	Fatheads
Wettable powder	0.1	0.1	0.1

Application range: 0.15 ppm

At rates non-toxic to warm-water fish (less than 0.1 ppm), this chemical has been ineffective as a control agent for blue-green algae.

4.3.8 Delrad, (Rosin amine D acetate)- - - -dihydroabietylamine acetate

Formulation	Concentration in ppm safe to Bass	Bluegill	Fatheads
Acetate	0.6	0.6	0.6

Application range: 0.25 to 0.50 ppm

This chemical has given varied results as an algicide in ponds. Under certain conditions a single application has given fair control of the branched algae Pithophora spp., and the net algae Hydrodictyon spp., and in other situations the chemical was practically inactive. The chemical was fairly rapidly deactivated in pond waters, thus adding to its inability to give reliable algae control. This deactivation was believed to have been due to exposure to ultra-violent light.

This chemical was fairly toxic to warm-water species of fish (maximum safe concentration was 0.6 ppm). When making marginal applications to ponds, young bluegills and bass caught in fairly high concentrations of the chemical have been killed. However, when the chemical was applied by the float technique, three applications of 0.3 ppm in ponds during the period bass spawned had no harmful effect upon the eggs or young fish.

In other pond tests, no difference in fish production in delrad-treated and untreated ponds was detected. This chemical was not toxic to the green or blue-green plankton algae present in treated ponds.

4.3.9 Diquat —1-1'-ethylene- 2,2'dipyridylium dibromide
-do- dichloride

Toxicity to fish

Formulation	Concentration in ppm safe to		
	Bass	Bluegill	Fatheads
Dibromide salt	20	20	20
Dichloride salt	20	20	20

Application range: 1 to 4.5 kg per ha; 0.2 to 1.0 ppm (cation)

This chemical at rates of 1 to 2 kg (cation)/surface ha has provided excellent control of many submersed and floating species of weeds. Herbicidal activity has usually been noted within a few hours. This herbicide was absorbed onto the mud and organic matter on the pond bottom within 14 days.

Diquat cannot be used in muddy or silty waters because of rapid adsorption onto suspended clay and organic particles. It is relatively ineffective on submersed weeds whose leaves and stems are silt- or algae-laden.

This chemical has produced a kill of the blue-green alga, Anabaena, within 24 hours at a concentration of 0.5 ppm. It appeared to be very toxic to mono-filamentous algae and produced 80 percent control of Pithophora at concentrations of 0.7 ppm.

Small amounts, say, 0.2 to 0.5 kg per ha of this chemical in combination with 2,4-D, fenac or similar compounds has produced more rapid and complete herbicidal activity on many submersed weeds than could be obtained with either chemical alone.

Mixed with water and 0.25 percent wetting agent, diquat at lower rate has provided control of marginal weeds, including grasses, for periods of six to eight weeks.

4.3.10 Paraquat —1:1' -dimethyl -4.4' -bipyridylium di (methyl sulphate) dichloride

Toxicity to fish

Formulation	Concentrations in ppm safe to		
	Bass	Bluegill	Fatheads
Di (methyl sulphate) safe	5	10	10
Dichloride salt	5	10	10

Application range: (1 to 4.5 kg per ha); 0.1 to 1.0 ppm (cation)

This chemical at rates of 1 to 2 kg(cation)/surface ha has provided more complete control of submersed weeds than diquat, but it is less effective as a control agent for floating weeds.

Herbicidal injury from paraquat is slower in appearing than with diquat, but under adverse conditions of an alga covering on plants, etc., is more certain to be achieved. Likewise the persistence of paraquat in water may be twice as long as for diquat.

As with diquat, this chemical is rapidly adsorbed onto clay and organic particles, thus it cannot be used in muddy or silty waters.

Paraquat has controlled the blue-green algae Anabaena, and Pithophora, at concentrations ranging from 0.5 to 1.0 ppm.

Mixtures containing equal parts of diquat and parquat have provided excellent control of submersed weeds and filamentous algae.

Combinations of paraquat and 2,4-D, fenac, etc., were equally effective as those using diquat.

4.3.11 Simazine—3-chloro-4,6-bis (ethylamino)-s-triazine

Toxicity to fish

Formulations	Concentrations in ppm safe to		
	Bass	Bluegill	Fatheads
Wettable powder	40	10	10

Application range: 2 to 11 kg per ha

At the higher rate, this chemical controlled all sumbersed and emersed weeds plus filamentous and plankton algae. Residual simazine was detected in water and soil for 18 months following treatment. Growth of filamentous and planktonic algae was severely inhibited for two summers, but for a much shorter period at the lower rate.

This chemical is relatively non-toxic to warm-water species of fish, but because of its algicidal properties it has interfered with fish production.

4.3.12 Diuron —3-(3,4-dichlorophenyl)-1,1 dimethylurea

Toxicity to fish

Formulation	Concentration in ppm safe to		
	Bass	Bluegill	Fatheads
Wettable powder	5	10 (laboratory) 1 (ponds)	15 (laboratory) 1 (ponds)

Application range: 1 to 11 kg per ha

Treatments in ponds located on piedmont and coastal plains soils were effective only at maximum rates on Pithophora and many submersed and emersed weeds. No regrowth of aquatic weeds or filamentous algae occurred in these ponds for six months.

Diuron at the higher rate seriously interfered with fish production in experimental ponds. Toxicity to fish became evident 14 to 21 days after the chemical was applied.

4.3.13 Borascu — Anhydrous polyborate

Toxicity to fish

Formulation	Concentrations in ppm safe to Bass	 Bluegill	 Fatheads
Salt	20	20	20

Application range: 110 to 225 kg per ha

Pond treatments at rates of 225 kg per ha gave a very limited degree of control of *Pithophora* and no control of either submersed or emersed weeds.

4.3.14 TCA-Trichloroacetic acid

Toxicity to fish

Formulation	Concentrations in ppm safe to Bass	 Bluegill	 Fatheads
Acid	10 plus	10 plus	10 plus

Application range: 2 to 18 kg per ha

The maximum rate provided no control of submersed aquatic weeds. A combination of minimum rate of TCA with 2,4-D and a good wetting agent provided effective control of cattail (*Typha* spp.)

4.3.15 Roccal, Alkyl-dimethyl-benzyl-ammonium chloride

Toxicity to fish

Formulation	Concentrations in ppm safe to Bass	 Bluegill	 Fatheads
Salt	1	1.5	1

Application range: 0.25 to 0.5 ppm

This chemical at maximum concentration has given rapid control of mono-filamentous algae for short periods (10 to 14 days) when the water temperature was below 70°F (21°C). At higher temperatures the chemical was ineffective as an algicide.

In addition to its algicidal properties, the chemical was an effective bacteriacide; thus it has been useful in combating certain infections of fish.

4.3.16 Amitrol—3 amino-1,2,4-triazole

Toxicity to fish

Formulation	Concentrations in ppm safe to Bass	 Bluegill	 Fatheads
Wettable powder	710	710	710

Application range: 1 to 5.5 kg per ha

This chemical showed certain herbicidal properties on emersed aquatic weeds, but when used alone provided poor control. In combination with some chlorophenoxyacetic compounds, amitrol has shown certain synergistic properties.

This chemical was relatively non-toxic to fish at fairly high concentrations, and has not exhibited any pathological effects on test fish.

4.3.17 Dalapon—2,2-dichloropropioniac acid

Toxicity to fish

Formulation	Concentrations in ppm safe to		
	Bass	Bluegill	Fatheads
Wettable powder	1000	80	710

Application range: 11 to 33 kg per ha

Maximum rates controlled marginal grasses in empty ponds when applied as a water spray with a watering agent.

4.3.18 AMS (ammata)—Ammonium sulphate

Toxicity to fish

Formulation	Concentrations in ppm safe to		
	Bass	Bluegill	Fatheads
Salt	10	10 m	10

Application range: 11 to 22 kg per ha

This chemical at maximum rate controlled certain submersed and marginal weeds in shallow water areas of ponds.

4.3.19 Diesel fuel

This material is fairly effective for temporary control of floating weeds when applied as a spray. It also increased the herbicidal activity of chlorophenoxyacetic compounds on emergent growths of aquatic weeds.

Rates of application in excess of 75 litres per ha (20 gallons per acre) have imparted flavours to fish for four to six weeks.

Diesel fuel application also controlled the air-breathing immature insects inhabiting treated ponds.

4.3.20 Fenac—2,3,6-trichlorophenylacetic acid

Toxicity to fish

Formulation	Concentrations in ppm safe to		
	Bass	Bluegill	Fatheads
Disodium salt	10	10	10

Application range: 5.5 to 11 kg per ha

This chemical, which is most effective herbicidally through the root system of plants, has provided partial to complete control of all submersed and emersed weeds in a pond for a period of 18 months or longer. It was most effective at the maximum rate indicated. It was ineffective in the control of Chara, Nitella and filamentous algae.

Due to its lack of algicidal properties, treatments at the highest rate indicated have had no harmful effects on fish production in ponds.

4.3.21 Dichlobenil (casoron)—2,6 dichlorobenezonitrile

Toxicity to fish

Formulation	Concentration in ppm safe to Bass	 Bluegill	 Fatheads
Wettable powder	2	2	2

Application range: 2 to 9 kg per ha

This is one of the most volatile compounds that has been tested as an aquatic herbicide. Herbicidal effectiveness upon emersed weed growth has been drastically different under laboratory and field conditions. A rate of 2 kg per ha applied as a spray completely killed alligatorweed within 10 days in the laboratory, while a rate of 9 kg per ha only acted as a defoliant in field spray applications.

Limited research to date shows some promise that underwater treatments at the rate of 9 kg per ha may control some submerged weeds.

The chemical was relatively non-toxic to fish and apparently decomposed rapidly and produced no effects upon fish production.

4.3.22 Endothal—3,6 endoxohexohydrophtalic acid
-do- (TD47, A1-4) -do- di,(N,N-dimethylalkylamine) salt

Toxicity to fish

Formulation	Concentration in ppm safe to Bass	 Bluegill	 Fatheads
Disodium salt	10	10	10
TD47, A1-4	1	1	1

Application range: 5.5 to 11 kg per ha; 1 to 2 ppm

Treatments of endothal at maximum rates have provided control of many submersed weeds for periods of four to eight weeks in pools and ponds. This chemical is primarily a contact type, thus its effects were of a temporary nature if the species present were capable of regrowth from root stocks. If the species was not capable of root stock regrowth, then the species could be eliminated by this treatment, provided no seeds were present to repopulate the treated area.

No algicidal properties were noted for this chemical at any rate of application.

The di (N,N dimethylalkylamine) salt of endothal enhanced its activity against numerous hard-to-kill water weeds, but this chemical eliminated the fish population wherever it was tested.

5 SPECIALIZED TECHNIQUES FOR EVALUATING AQUATIC HERBICIDES

5.1 Laboratory methods

Techniques were developed for culturing submersed and emersed aquatic plants under artificial light at a constant temperature.

Standardized techniques were also developed for treatment of submersed and emersed aquatic weeds with a candidate herbicide, and for evaluating the resulting herbicidal activity upon test plants.

A total of 1,500 different chemical compounds were evaluated by these laboratory methods. Only 120 of these compounds exhibited 95 percent or greater overall herbicidal activity at a concentration of 5 ppm active ingredients. Only 16 of these herbicidally active compounds were non-toxic to fish at 10 ppm (Lawrence, 1964b).

The general susceptibility of test plants from least to highest susceptibility to all of the chemicals tested was as follows: alligatorweed, Pithophora, stargrass, Brazilian elodea, waterthread pond weed, southern naiad, common duckweed, waterhyacinth.

5.2 Plastic pool method

Techniques were developed for culturing communities of submersed, emersed and floating weeds in shallow plastic pools whose bottoms were covered with soil. This research has provided a better understanding of conditions conducive to the establishment of weed communities in ponds, as well as their long-term (one year) effects upon fish and fish-food organisms production under simulated field conditions in plastic pools (Lawrence, 1964a).

A total of 105 replicated herbicidal treatments have been evaluated by the plastic pool technique. The succeptibility of aquatic weeds to herbicide in these pools was of the same general order as that given for laboratory tests.

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VII/E-2

INVESTIGATIONS ON AQUATIC WEED CONTROL WITH SPECIAL REFERENCE TO THE USE OF CHEMICALS

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Abstract

Various aspects of the control of aquatic weeds in India are discussed in the light of the authors' experiences and findings. Emergent weeds such as *Eichhornia crassipes*, *Pistia stratiotes*, *Nymphaea* sp. and *Cyperus* sp. have been cleared in field trials with sodium salt of 2,4-D. *Hydrilla verticillata* and *Ceratophyllum demersum* have been controlled with ammonia. Observations have been made on the manual clearance of floating and submerged weeds. Details of weedicide treatments and results achieved are described. A simple field technique of effective spot treatment of thick water hyacinth infestations is described. An attempt has been made to correlate the weight of the plant, the quantity of weedicide necessary for its kill and the capacity of the spraying unit, in order to evolve an empirical method of calculating the dose and

dilution of the weedicide solution. Some observations are made on the effect of weather on the action of the herbicides and on the use of additives for enhancing this action. Simazine at 1 ppm could control Microcystis aeruginosa and at 3-5 ppm, Hydrilla verticillata. At a dose of 40 ppm sulphur dioxide also could kill Hydrilla. Findings on the nature and extent of the toxicity of ammonia and its effectiveness in clearance of submerged weeds are reported. Criteria for evaluating the success of clearance of submerged weeds are proposed. Points to be considered before deciding upon any plan of weed control are discussed.

ETUDES SUR LA LUTTE CONTRE LA VEGETATION AQUATIQUE NOTAMMENT A L'AIDE DE PRODUITS CHIMIQUES

Résumé

Divers aspects de la lutte contre la végétation aquatique en Inde sont examinés à la lumière du résultat des expériences effectuées par les auteurs. Au cours d'essais sur le terrain, des plantes émergées telles que Eichhornia crassipes, Pistia stratiotes, Nymphaea spp. et Cyperus spp. ont pu être éliminées avec du sel de sodium de 2,4-D. L'ammoniaque a donné de bons résultats dans la lutte contre Hydrilla verticillata et Ceratophyllum demersum. Il est rendu compte d'observations concernant l'élimination manuelle de la végétation flottante et submergée. Des précisions sont données sur les traitements avec des herbicides et les résultats obtenus. Une méthode simple pour le traitement efficace des infestations denses de jacinthe d'eau est décrite. Les auteurs ont essayé d'établir une corrélation entre le poids de la plante, la quantité d'herbicide nécessaire pour la détruire et la capacité de l'appareil de pulvérisation, afin de mettre au point une méthode empirique permettant de calculer la dose et la dilution de la solution herbicide. Certaines observations ont été faites concernant l'effet des conditions météorologiques sur l'action des herbicides et sur l'utilisation d'additifs pour renforcer cette action. La simazine à 1 ppm permet de détruire Microcystis aeruginosa et, à 3-5 ppm, Hydrilla verticillata. A raison de 40 ppm l'anhydride sulfureux est également efficace contre Hydrilla. Il est fait état d'observations relatives à la nature et au degré de toxicité de l'ammoniaque et à son efficacité pour la destruction des plantes immergées. Les auteurs proposent des critères permettant d'évaluer la réussite obtenue dans la lutte contre les plantes immergées. Enfin, ils examinent les éléments dont il y a lieu de tenir compte avant d'entreprendre un programme de lutte contre la végétation.

INVESTIGACIONES SOBRE LA LUCHA CONTRA LAS MALAS HIERBAS ACUATICAS CON ESPECIAL REFERENCIA AL EMPLEO DE PRODUCTOS QUIMICOS

Extracto

A la luz de las experiencias y conclusiones de los autores se discuten varios aspectos de la lucha contra las malas hierbas acuáticas en la India. Plantas emergentes, tales como Eichhornia crassipes, Pistia stratiotes, Nymphaea spp. y Cyperus spp. han sido eliminadas en ensayos de servicio con sal sódica de 2,4-D. Se ha combatido Hydrilla verticillata y Ceratophyllum demersum con amoníaco. Sobre la supresión manual de las hierbas flotantes y sumergidas se han efectuado observaciones. Se dan detalles de los tratamientos con herbicidas y de los resultados logrados. Se describe una sencilla técnica de campo sobre el tratamiento efectivo localizado de infestaciones de jacinto de agua. Se ha tratado de correlacionar el peso de la planta, la cantidad de herbicida necesario para su eliminación y la capacidad de la unidad fumigadora, a fin de desarrollar un método empírico de calcular la dosis y la dilución de la solución de herbicidas. Se hacen algunas observaciones sobre el efecto del tiempo atmosférico en la acción de los herbicidas y sobre el empleo de aditivos para incrementar su acción. Simazine al 1 ppm podría combatir Microcystis aeruginosa y a 3-5 ppm, Hydrilla verticillata. A la dosis de 40 ppm, el dióxido de azufre podría también destruir Hydrilla. Se dan noticias de las conclusiones sobre el carácter y amplitud de la toxicidad del amoníaco y su eficacia en la supresión de plantas sumergidas. Se proponen criterios para evaluar el éxito de la eliminación de tales plantas. Se examinan, asimismo, los extremos que deben tenerse presentes antes de decidir sobre cualquier plan de lucha contra las mismas.

1 INTRODUCTION

In view of the seriousness and magnitude of the problem of weed infestations in fishery waters in India, utmost attention is being paid to this problem both in the field and in the laboratory.

Though the several conventional weedicides such as arsenicals and copper compounds and the more recent ones like hormone weedicides Simazine and a host of other formulations (already reported effective by other workers elsewhere) provided the necessary lead, considerations of the availability, cost, toxicity to animals and humans and possible adverse effects upon the fishery, etc., have severely limited the choice of materials. A good deal of specific investigations had therefore to be carried out before any headway could be made in evolving standard field recommendations suitable for conditions in the Indian countryside. With this end in view, a large number of field trials and observations in different parts of the country under widely varying conditions, have been carried out. Initial selection of the weedicides, additives and doses and studies on the nature and extent of damage to plants were made in laboratory and yard experiments.

2 NATURE OF WEED INFESTATIONS IN INDIA

During the extensive surveys of natural waters in various parts of India, it has been observed that in larger areas floating and emergent weeds are by far the most extensive (Philipose _et al._, 1962a and b). When these are cleared and controlled, it has been observed that submerged vegetation comes up instead, most likely from dormant reproductive parts of these plants left over when the submerged vegetation was predominant. Perennial blue-green algal blooms are usually found in old tanks with excessive organic ooze at the bottom or in those subject to city sewage or other pollution. In such tanks practically no submerged weeds grow. The nitrogenous and phosphorus contents of these waters are abnormally high. Conversely, where submerged weeds grow in abundance, the water is usually very clear, being practically devoid of microflora. Such waters are almost invariably very poor in dissolved phosphate. It has also been observed that the surface-choking floating weed (_Lemna_ spp.) is associated with high phosphate content of the water (Alikunhi, _et al._, 1952).

3 INVESTIGATIONS ON THE METHODS OF CONTROL

The field operations for aquatic weed control are generally carried out in two phases, viz., initial clearance and subsequent maintenance. Of these, the former is the more difficult and more immediate problem and has therefore received greater attention so far. As already referred to, a large number of agricultural weedicides and commercial chemicals and fertilizers have been tested and tried. Some of the more significant experiences with different types of weeds are presented below.

3.1 _Water hyacinth (Eichhornia crassipes)_

Though it is well known that this weed is susceptible to 2,4-D formulations, a number of fishery workers in India who have tried them (Philipose, 1957; Chakravarti, 1963), have expressed differing opinions on the formulations, doses, effectiveness and suitability.

The present authors' experience so far has been that both total kill and complete decomposition of the infestation could be achieved, resulting in natural clearance of the water surface provided an adequate dose is applied in a proper manner in the proper season uniformly all over the area. Though the aqueous solution of the 2,4-D sodium salt 80 percent (Taficide-80) by itself achieves total kill of the infestations, at the rate of about 4 to 6 kg per hectare, the effect seems to be quickened by the addition of a small quantity of a detergent Surf to the aqueous solution. In two experimental plots, one treated with Taficide-80 alone at the rate of 6 kg/ha and the other plot with the same weedicide at the rate of 4 kg/ha, plus the detergent Surf at 0.1 percent concentration, the epinasty of the leaves in the latter plot not only equalled that of the other one in extent, but the progress was also much quicker.

The plants were very susceptible to 2,4-D treatment in summer and the effect was found to be rapid in that season. The water spread in the area was also at its lowest. Warmth, humidity and subsequent rainfall in the monsoon season helped quick decomposition and dissolution of the killed vegetation, thus freeing the water surface. On the other hand, treatment in winter may not give quick results because of the slowness of translocation, death and decomposition of the infestation, which may float, choking the water surface for a very long time. Further, the presence of a large number of old, tall, dry leaves during winter is bound to hamper effective spraying of the green shorter young leaves (FAO/UN, 1954; Ramachandran, 1963a).

The present authors found that heavy rainfall within even two hours after spraying a 1.5 percent concentration of 2,4-D Sodium salt in water did not make the treatment less effective. Air temperature at the time of treatment was about 30°C. Initial effects appeared within 72 hours after treatment. The green leaves turned yellowish or brown and the leaf stalks were etiolated. After about a week the foliage dried up. The bulk of the roots and runners was considerably reduced. The plants thus affected never revived though they floated about on the surface till the slow process of natural decomposition ultimately consumed them. However, there were a few patches of untreated or insufficiently treated plant clumps in the area which remained comparatively fresh and viable. When these were located, they were treated with the weedicide spray or, if convenient, manually removed as otherwise they tended to reinfest the freed water surface.

There was no mortality of fishes. On the contrary, several carp (Indian major carps, *Catla catla*, *Labeo rohita* and *Cirrhina mrigala*) fingerlings were seen nibbling at the dead floating weed mass. Saha *et al.* (1958) also could not observe any mortality of Indian major carps on complete destruction of water hyacinth with 2,4-D treatment.

3.1.1 Technique of treatment

As already stressed, the success of weedicide treatments depends upon ensuring thorough and uniform coverage of the entire field in as short a period as possible. Water hyacinth infestations are most often so thick that even a small boat cannot be pushed through. Hence the approach to the interior of the infested area for effective spraying has been difficult. Based on some initial observations, a very simple method has been adopted which may be found quite convenient for most of the areas, particularly in rural India where methods of aerial spraying are unavailable or too costly.

A stout but hollow and light bamboo pole laid on top of dense infestations of water hyacinth is usually quite capable of carrying a man with a sprayer. He could walk on this bamboo pole from end to end, if necessary, with the help of a prop. On reaching the farther end another such bamboo pole laid close and parallel to the first could be pushed further up. In this manner, an entire area of thick infestations over 150 metres across has been treated in continuous operation.

Other details pertaining to the treatment and clearance of water hyacinth infestation with Taficide-80 carried out by the present authors are given below:

Effective dose of the weedicide, Taficide-80 : 4 - 6 kg/ha

Concentration of the weedicide in aqueous solution for spraying : 1 percent-1.5 percent

Detergent used and concentration: Surf (a patented household detergent available in India). - 0.25 percent in the weedicide solution.

Spraying equipment : Knapsack or stirrup pump sprayer (the latter to be operated from the shore delivering through long polythene tubing carried into the interior of the infested area).

Spray nozzle: Stainless steel cone jet nozzle

Initial pressure build-up in the sprayer: 3.3 - 5 kg/sq cm

Time taken to deliver 10 litres solution in continuous discharge : 30 - 40 minutes

Area covered with 10 litres aqueous solution : 250 sq m

Density of infestation : About 40 - 50 kg per sq m (As already mentioned, a maximum of even 115 kg/sq m has also been encountered.)

Time taken for complete clearance of water surface : 3 months

Increase in the fertility of the water on death and dissolution of an infestation of 40 kg/sq m : 0.6 ppm phosphate in a depth of 1 m of water

Manual labour required for treatment : 160 man hours/ha

Total cost of clearance: About Rs.112/- per hectare (U.S.$ ca.23.6)

Preliminary experiments under laboratory conditions seem to indicate that at least 0.75mg of the weedicide per each plant (Taficide-80) is needed to achieve complete kill of young water hyacinth plants in the weight group of about 100 g. Complete kill of even small plants of about 30 g weight could not be achieved with 0.5 mg of the weedicide per plant. The application was made on a single old but green leaf of the plant with a 1 percent aqueous solution of the weedicide. The growing shoot and the runners were the first to show epinasty.

3.1.2 Other weedicides

Simazine at the rate of 5 kg active ingredient per hectare sprayed as an aqueous emulsion was able to kill and clear water hyacinth infestation, but it is not considered suitable for use in India on account of its high cost. Other formulations of weedicides have not been tried because of either non-availability or high cost.

3.1.3 Manual clearance

In rural India water hyacinth infestations are generally cleared by manual labour. In some cases where the area is subject to annual flooding and overflow, huge patches of the weed are steered out into the main stream and the area cleared. In water areas with steep embankments, the marginal area is first cleared by lifting and throwing out the weeds, (Fig. 1), and then the interior mass is cut into blocks, dragged ashore and removed. This, of course, is laborious and often expensive. About 1,800 man hours of labour was needed to clear one hectare in this manner. The cost of this labour is found to be excessive under present conditions.

3.2 Other floating weeds

Other floating weeds such as *Pistia stratiotes*, *Spirodela polyrhiza*, *Lemna minor*, *Azolla pinnata* and *Wolffia arrhiza* do not pose any serious problem of clearance. A fairly thick and thorough infestation of the bulkiest among these weeds, viz., *Pistia stratiotes*, yielded only about 1.4 kg weed mass per square metre, i.e. approximately about 3 percent only of the bulk of water hyacinth in a similar environment. For eradicating these, manual labour is still the easiest in India. With a shallow (about 1 m height) wide-meshed (about 3 cm) coir rope net the infestation can be easily skimmed out. Removal of small-leafed weeds such as *Spirodela polyrhiza*, *Lemna minor*, etc. is also achieved by skimming out with a long rope of straw.

Fig. 1 Clearance of water hyacinth infestation by manual labour

Fig. 2 Spraying weedicide on marginal grasses

Thomas and Srinivasan (1949) succeeded in eradicating *Pistia stratiotes* by applying M.C.P.A.(2,4-D ester) at 8 - 12 lbs/acre[1] at 0.2 percent concentration. Simazine at 20 - 25 lbs/acre and Diquat 3 - 5 ppm are reported to control *Pistia stratiotes* (Lawrence, undated). Among the chemical weedicides tried by the present authors, Simazine and Taficide-80, both at a dose of 5 kg/ha, achieved effective kill of *Pistia stratiotes* in the field. The glabrous leaf surface of *Pistia* prevented effective wetting with simple aqueous solution of Taficide-80, at 1 - 1.5 percent concentration at 5 - 6 kg/ha, and so the effect was slow. But it was very much quickened with the addition of Surf to give 0.25 percent concentration. This simple mixture gave a better and quicker effect at a cheaper cost than a wettable butyl-ester formulation of 2,4-D (Dicotox). Aqueous emulsions of wettable Simazine formulation, however, do not seem to need addition of any detergent. In one case it was observed that 2,4-D treatment, even with detergent added, could not kill a *Pistia stratiotes* infestation, probably because the treatment was carried out in winter and the plants were too old.

Ammonia at a concentration of about 40 ppm N applied uniformly near the water surface also kills all these plants. Not many large-scale field trials with ammonia on these infestations have been carried out.

3.3 Emergent weeds

Among the rooted emergent vegetation, *Nymphaea nouchali*, *N. stellata* (water lilies), *Nelumbo nucifera* (lotus) and *Nymphoides cristatum*, and *N. indicum* are the weeds that pose any problem of real magnitude.

On the use of 2,4-D for control of water lilies including *Nymphaea* spp. Surber (1948a), Snow (1949) and Cornell (1949) have stated that the plants were only partly affected and that more than one application may be needed to kill the plants. The present authors found that just one application of 2,4-D sodium salt 80 percent at about 1.5 percent concentration with detergent added (Surf 0.25 percent - 1 percent concentration) could achieve complete uprooting of all the lily plants (*Nymphaea nouchali* and *N. stellata*) and further clearance operation consisted of only picking up the floating plants from a boat or dragging the surface with a rope. The leaves of the plants are not drastically affected except for a little crinkling of the edges and elongation and twisting of the leaf stalks.

Addition of detergent to 2,4-D aqueous solution was found essential for wetting the leaves for treatment of lotus. The results of the treatment were not conclusive.

Treatment of infestations of *Nymphoides cristatum* and *N. indicum* with 2.5 percent aqueous solution of Taficide-80 with detergent added could completely defoliate the plants of which several clumps were also uprooted. However, a large number of plants remained rooted even after losing all the leaves, and regenerated quickly.

3.4 Shallow water and shore weed infestations

Cyperus spp., *Phragmites* sp., *Eleocharis* spp. and *Panicum* spp. among the grasses and sedges and *Colocasia antiquorum* and *Ipomoea aquatica* among the broad-leafed vegetation constitute the common weeds of this category.

In India very little work on the control of aquatic grasses and sedges with chemical weedicides has been done. Recently, however, the authors could achieve total kill of young *Cyperus* sp. plants with 1 percent aqueous solutions of both Taficide-80 and Tafapon (2,2-Dichloropropionic acid sodium salt 85 percent) at the rate of 28 kg per hectare. In a laboratory experiment on the effect of foliar treatment of the weedicide addition of a little calcium chloride (0.1 percent concentration) to the weedicide

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[1] lbs/acre x 1.12 = kg/ha

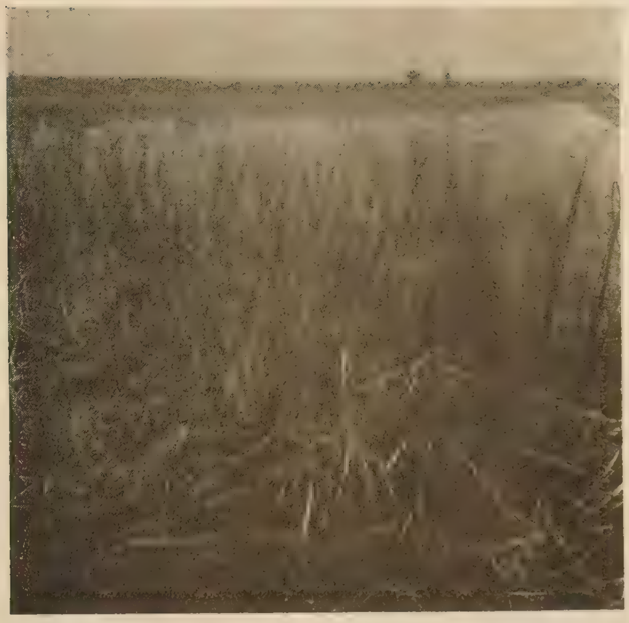

Fig. 3 The effect of weedicide treatment on marginal grasses a month later. Note that only the plants which have flowered are left standing.

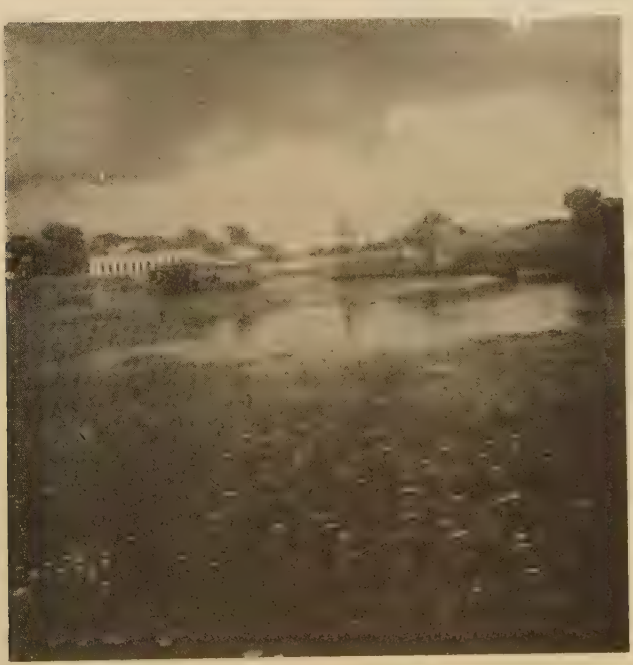

Fig. 4 A big, deep tank choked with Hydrilla and Nymphoides, part of which was cleared by manual labour.

seemed to hasten the effect. In field trials also the latter chemical was used with a view to keeping the weedicide moist on the tall grasses for longer periods to achieve better absorption. Other workers as quoted by Vaas (1951) have used a hygroscopic glycerine compound for the same purpose and have reported better kill of water hyacinth.

Uniform and economical spraying of the weedicide solution on tall grasses could be done by attaching the sprayer nozzle to a long light pole (Fig.2).

The older plants, particularly those that have already flowered, seemed to be resistant to the treatment (Fig.3). Tafapon alone even at a dose of 40 kg ha could achieve only drying of the leaf tips in an old mature flowering stand of Cyperus sp.

Eleocharis plantaginea plants have been badly affected by 2.5 percent aqueous solution of 2,4-D with detergent added at 0.25 percent concentration.

Panicum fluitans, in preliminary laboratory trials could be killed by root application of 2,4-D as well as Simazine (Patnaik, unpublished data).

Colocasia antiquorum sprayed with aqueous solution of Taficide-80 at a concentration of 1.5 percent with the addition of Surf could cause curling of the leaf lamina and elongation and drooping of the leaf stalks. The plants thus affected get uprooted and float. Their physical removal is then an easy matter. If not physically removed at this stage, they seem to revive and strike roots again.

3.5 Planktonic algal blooms

The blue-green algae, particularly Microcystis aeruginosa is the most obnoxious of this category, in India. Several weedicides including copper sulphate have been used for control of planktonic algae as reviewed by Lawrence (d.u.).

Our preliminary screening experiments in jars and cement cisterns with Simazine indicate that even a small dose of 0.5 - 1 ppm active ingredient could effectively control the blue-green algae. This weedicide is not toxic to fish or zooplankton at the above dose. Its long-range effect on plankton successions in natural ponds has yet to be investigated.

Sarig, et al. (1960) have successfully used ammonia for control of the algae Prymnesium. However, in the preliminary laboratory experiments carried out by the present authors, ammonia at 10-15 ppm N could not control Microcystis aeruginosa, but rather sustained it.

3.6 Submerged weeds

In this category of aquatic weeds, Hydrilla verticillata, Najas graminea, N.indica, Ceratophyllum demersum, Vallisneria spiralis and Potamogeton spp. are the most formidable. The problem of the initial clearance of these infestations is far more difficult than in the case of other categories of weeds.

3.6.1 Manual and mechanical methods

Manual clearance is the most popular and easy method adopted in India. The thoroughness and efficacy of this method is subject to so much variation as to render any useful general conclusion impossible. One of the most efficient field operations observed so far was carried out in a large (about 5 ha) temple tank by two parties of labourers, each consisting of 13 men, (Fig.4). The density of the infestation mainly Hydrilla verticillata was 45 kg/sq m, along with Nymphoides cristatum in some patches (3.5 kg/sq m) in a depth of 2.75 m. The operations essentially consisted of cutting the roots of huge blocks of weed mass, and with the help of bamboo poles and ropes, dragging

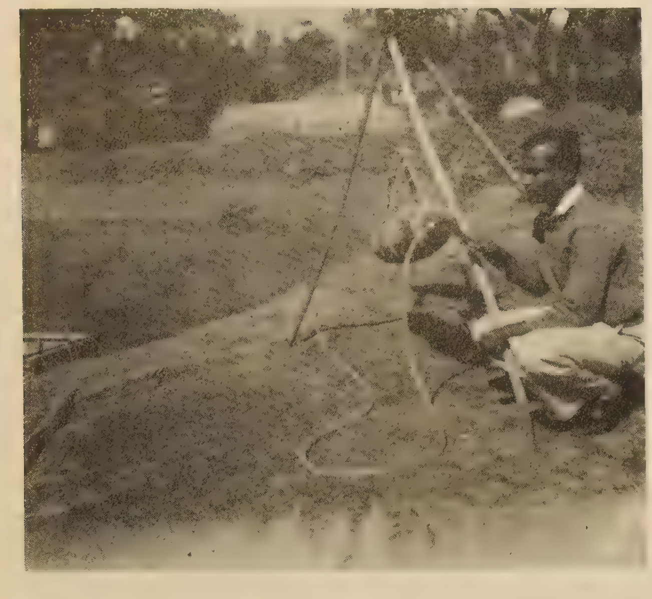

Fig. 5 Ammonia cylinder being weighed and set ready for ammonia application through polythene tubing.

Fig. 6 The multi-nozzle applicator on the stern of the boat from which it is to be suspended into the water.

Fig. 7 The boat, from which the applicator has been suspended into the water, being pulled across the pond while applying ammonia.

the weed mass ashore. It was possible in this manner to clear 2 ha area in about eight days. The clearance achieved was almost complete, but quick regeneration was reported within three months during August to October.

On the other hand, there has also been an instance where six labourers could achieve practically no clearance of Najas infestation in a very shallow water of about 1 m depth and 1 hectare area. This failure was due to quick regeneration of the weed (Najas sp.) in the early summer months.

Among methods where mechanical power has been used for clearance, mention may be made of the use of a power winch which was used to pull ashore weed masses by means of steel rope looped around sizeable sections of the infested areas. The effectiveness of clearance thus achieved was considerable. Regeneration, however, was very rapid. Where the winch could be used as frequently as necessary, good control could be achieved in the long run.

3.6.2 Chemical weedicides

Among the conventional weedicides tried by the authors, sodium arsenite at about 6 ppm concentration has given good clearance in most of the cases. Maximum effect was observed in a few weeks after the application. After clearance, where the area remained unattended, reinfestation occurred after one year. There was no large-scale mortality of fishes on account of the treatment. Commercial quality arsenicals, however, are not easily available now in India.

Following the recommendations of Smith and Swingle (1942), Surber (1948b), and Arle (1956) to use fertilizers, urea was successfully used by Philipose and Ramachandran (unpublished) in shallow infested waters at a high dose of 250 ppm or more. Large-scale mortality of fish occurred. Detailed laboratory investigations indicated the toxic effects of free ammonia upon the fish and the vegetation, as reported by Ramachandran (1960). Following this, a method and a suitable technique (Fig. 5 to 7) of clearing submerged weed infestations with anhydrous ammonia have been evolved and several successful field trials carried out (Ramachandran, 1963a).

Further work has shown that:

(i) low pH with free carbon dioxide or any acidic condition of the water could largely nullify,while high pH enhances the toxicity of ammonia,

(ii) considerable proportion (25-30 percent) of the applied ammonia enters the productive cycle of the water,

(iii) even four hours exposure to 10-20 ppm N of ammonia caused considerable damage to Ceratophyllum demersum. (A pond of about 0.2 ha area and about 1 m depth fully choked up with the above weed was cleared to an extent of 80 percent with about 22 kg of ammonia),

(iv) exposure of Hydrilla verticillata turions to aqueous ammonia with 10 ppm N seemed to quicken their germination, and

(v) toxicity of ammonia tended to be slightly translocated from the roots upwards, when exposed to 16 ppm N.

A dense infestation (30 kg/sq m) of Hydrilla verticillata has been cleared to an extent of over 93 percent (in terms of bulk) by use of ammonia at about 15 ppm N. Of the residual weed debris constituting about 7 percent of the bulk, as much as possible was removed by manual-mechanical methods.

A quantitative study of re-infestation showed that even after nine months, only less than 20 percent of the original mass of weeds had grown. This tends to confirm the hope that with one or two clearances carried out before the maximum turion-forming season (December-February) it may be possible to practically eradicate weed infestation in the pond.

Among other weedicides tested for the control of submerged weeds, Simazine at about 3-5 ppm active ingredient and Aquathol (19 percent technical Endothal; i.e Disodium 3,6 endoxohexa hydrophthalate) were found effective against Hydrilla verticillata. Field trials with these have not been carried out because of the high cost of the former and non-availability and toxicity of the latter.

Sulphur dioxide at about 40 ppm in the form of bisulphite in acidic medium has also been able to achieve effective kill of Hydrilla verticillata grown in cement cisterns. Though sulphur dioxide is available in bulk quantities in anhydrous liquid form or as bisulphites, large-scale field trials have not been carried out because ammonia was found to be far more promising.

4 DISCUSSION

The occurrence and nature of aquatic weeds in an area seem to be governed by several complex factors. Some of these have been briefly dealt with by Philipose et al. (1962a and b). The absence of submerged macrovegetation in sewage polluted waters supporting algal blooms, as observed by the authors, may be due to some undetermined antagonism between the micro- and macroflora or due to the presence of excess of ammonia-forming organic matter in the environment or due, partly at least, to the effect of shading by the algal blooms. In this connection it is significant that Sigalov (1958) has reported that thio-cyanogen compounds present in sewage waters are effective herbicides. The association of Lemna spp. with high phosphate in water may be just incidental to the oxygen depleted, reducing conditions obtaining in such waters which favour release of immobilized phosphorus.

Deprivation of nutrients, particularly phosphate, from the medium in waters choked with submerged weeds might be one of the principal reasons for the absence of microflora in such waters.

In India water hyacinth is, admittedly, the one single weed which totally renders waste large areas of cultivable waters. It has therefore deservedly attracted the most scientific attention since Parija (1934) carried out physiological investigations on the plant. Though successful control has been reported with arsenical spray (Choudhury, 1956), most of the workers have preferred to use 2,4-D formulations. Wide ranges of doses and concentrations have been reported effective.

As reviewed by Chakravarti (1963) the concentrations of 2,4-D tried ranged from 0.05 to 2.0 percent and Hildebrand (1946) has found 0.1 percent to be sufficient. This might have been due to the wide range of density of infestation and individual plant conditions, as indicated in this paper. Snow (1949) emphasized that the amount of spray materials required to treat a given area varies and depends upon the species, the density of growth and age of weeds. On the other hand Williams, Slife and Hanson (1955) found age at the time of 2,4-D application was of little importance if the plant was sensitive but the tolerance among resistant species tended to increase with age. Thus there seems to be an obvious need for a quantitative approach towards evolving standard procedures for eradication. Though Vaas (1951) has stated that to eradicate older plants a higher dose is necessary, no attempt seems to have been made to evolve precise prescriptions, correlating the plant condition, densities of infestations and doses of weedicides. As an example, on the basis of the initial experiments previously reported in this paper, we may suggest an empirical method of prescribing the dose as follows:

Number of plants per square metre:	about 60
Condition of plants:	fresh, young and average weight 1 kg each
Quantity of weedicide to achieve total kill of plant of 1 kg wt as determined in laboratory trials:	10 mg approximately
Total quantity of weedicide to achieve complete kill of all the plants in 1 ha (10,000 sq m):	600 mg x 10,000 = 6 kg

Having decided the total quantity of weedicide needed, we may then prescribe the concentration of the weedicide solution.

With the available spraying equipment and approach technique, if we can thoroughly spray 250 sq m with 10 litres of solution, we shall need: $\frac{10000}{250}$ x 10, i.e. 400 litres of solution. It is therefore obvious that the strength of weedicide solution should be 6000/400 = 15 g /litre or 1.5 percent.

It is realized that the above method of deciding the dose and concentration may represent an over-simplification, but on the lines indicated, a practical prescription taking into account, if necessary, atmospheric temperature, quantity of detergent etc., may have to be evolved to avoid uncertainties, wastages or insufficiencies.

Regarding the influence of temperature, Barrier and Loomies (1955) state that increasing the temperature by 10° C doubles the rate of absorption of 2,4-D. This, as well as the views of Botke (FAO/UN, 1954) Saha, Sen and Muhury (1958) are in conformity with the present authors' findings of the good response of plants (*Pistia stratiotes*) treated in summer and the failure of the same treatment in winter.

According to the authors' findings, rainfall within even two hours after spraying (air temperature about 30° C) made no difference to the effectiveness of the weedicide even though Snow (1949) had stated that rainfall within 12 hours of spraying will decrease the effectiveness of spraying. Vaas (1951) also reported that rainfall half an hour after spraying had no influence, provided conditions for assimilation and transport were favourable. The difference in these findings might be due to the widely different thermal conditions at which the experiments were conducted and also, possibly, different conditions of the plants. All these different findings go to emphasise, as we have already done, the importance of a combined quantitative expression of the findings taking into account all the influencing factors.

Commenting on the spraying equipment, Botke (FAO/UN, 1954) has categorically stated that power sprayers will be needed for treating large areas. The authors, however, found it possible to treat large areas (more than 1 ha) by employing light, manually operated sprayers (several units if necessary) by the technique already mentioned. It is evident that the area that can be covered uniformly in a given time depends not only upon the speed with which the weedicide is delivered, but also upon the speed of movement of the operator in the interior of thickly choked areas. If high-speed power sprayers are to be effectively used, correspondingly speedy methods of movement of the operator in the choked area must be adopted.

Fine fog-like spraying seems to be the best form of delivery. This prevents too heavy loading of the leaf surface with the weedicide solution, which may then run off. Vaas (1951) had also reported that a fine nozzle and atomized spray help in reducing spraying costs.

Regarding chemical destruction of dense weed infestations, the average Indian fish culturist asks two pertinent questions; viz. whether the settling weed mass will not considerably add to the silt deposit at the bottom and whether it will not cause large-scale mortality of fishes. The senior author in an earlier paper (Ramachandran, 1963a) has pointed out that in an infestation even as dense as 115 kg of plants per square metre, the debris was not thicker than 1 cm and this organic mass would gradually decompose and disappear. This slow process of decomposition of organic matter consisting mainly of fibrous cellulose matter does not cause any sudden depletion of oxygen or pollution even in a shallow water area (1-1.5 m depth) as to lead to mass mortality of fishes. On the contrary, the uncovering of the water surface might facilitate oxygenation of water.

Writing on the selectivity of 2,4-D and related compounds, Blackman (1963) states that the selectivity depends upon differential retention, the amount entering through the shoot or the root coupled with the subsequent distribution and accumulation in different parts of the plant. In this light, it seems possible that by addition of well-chosen additives to the active ingredients of the weedicides in proper concentrations, we may enhance the retention, penetration and internal transport of the weedicide and thereby combat the resistance exhibited by so many noxious aquatic weeds to the hormone weedicides. Absorption of 2,4-D is reported to be increased by 800 percent to 1000 percent by the addition of wetting agents (Barrier and Loomis, 1955). The present authors found that the addition of a little detergent powder to an aqueous solution of Taficide-80 is much cheaper and more effective against Pistia stratiotes than using expensive wettable ester formulations of 2,4-D (Dicotox - Butyl ester of 2,4-D).

As already mentioned, the advantage of adding hygroscopic materials to weedicide solution also seems to have been realized (Hildebrand 1946; Vaas 1951). Calcium chloride might perhaps be a cheaper substitute compared to the patented glycerine formulations used. Anyway, the advantages derived, as indicated in this paper, seem to be promising and deserve further experimentation. Use of a hygroscopic material for treatment of tall grasses may be particularly necessary because the vertical stems and leaves rise high above the water level and are more exposed to wind action which might dry the weedicide solution on the leaves too quickly to enable sufficient absorption.

Even an ideally planned and executed field operation by any particular method cannot ensure 100 percent clearance. The present authors have learnt to consider that the success of a clearance operation may have to be judged by the extent to which the next follow-up operation is made easy. For example, in the case of water hyacinth infestation the minimum criterion of success of the initial treatment should be easy propulsion and manoeuverability of a boat in the area. In the case of submerged infestation, drag netting must be made possible. Likewise, we may suggest different criteria to judge the effectiveness of a weedicide against different types of weeds. In the case of submerged weeds most of which do not depend much upon roots for their survival, the reduction in bulk may be taken as the criterion. For weeds like lilies, lotuses, Nymphoides, grasses and Colocasia for which their rhizomes and roots are vital for survival and growth, the irreparable damage which their rhizomes and roots suffer may be the criterion. When their roots are killed, the plants most often get uprooted.

5 CONCLUSION

Since the ultimate purpose of all weed control investigations in fish ponds is to enable easy, effective and economical control of all aquatic weeds in large bodies of waters, laboratory screening experiments with different commercial weedicides on individual species of plants only touches the fringe of the real problem.

In undertaking field operations, clear conceptions of the purpose, the scope and the economies of each specific case have to be formed, before selecting any particular method and technique. At least approximate answers have to be found to relevant questions such as whether the likely cost of the entire weed control operations will be compatible with the relative costs of other operations such as manuring, clearing up of predators, stocking and harvesting. If in the light of these considerations, it is decided to reclaim a weed infested area, the field operations may be carried out in two phases: viz., initial clearance and subsequent maintenance. Of these, the former is more formidable. Small-scale field trials or yard experiments do not give a correct idea of the final outcome of the interplay of all the vital factors in large bodies of waters which greatly modify the effects. Conditions like shallow water, deep water proportions, actual depth of water, thermal stratification, light intensities at different depths, atmospheric conditions, chemical conditions of water, particularly its pH, alkalinity and carbon dioxide content, biological conditions such as bacterial and fish population, distribution of regenerative parts, depth of embedding of roots and the age and weight of plants have to be given consideration in a comprehensive plan of weed control in every instance.

In choosing the weedicide materials and methods it must be borne in mind that for fish culture in India where larger bodies of water are to be stocked, the fish yield must largely depend upon the natural fertility of the soil and water. Hence physical removal of weeds from the area should not be preferred. The nutrients locked up in the weed mass must be returned to the ponds. The weedicide should not leave in the environment any residue, the accumulation of which may inhibit the natural productivity in the long run.

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EVALUATION OF EIGHT SPECIES OF FISH FOR AQUATIC WEED CONTROL [1]

by

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VII/E-3

EVALUATION OF EIGHT SPECIES OF FISH FOR AQUATIC WEED CONTROL

Abstract

A study was undertaken to determine the value of herbivorous fishes in biological control of aquatic weeds. *Ctenopharyngodon idella* controlled a wide variety of weeds when stocked in ponds at 49 to 99 per ha. Common carp, *Cyprinus carpio,* controlled filamentous algae and *Eleocharis acicularis* when stocked at 124 per ha. In this experiment common carp were not detrimental to fish populations when stocked at the above rate. *Tilapia melanopleura* controlled filamentous algae and a variety of higher plants when stocked at 2,470 to 4,940 per ha. At this stocking rate *T. melanopleura* did not produce adverse effects on other fishes. *T. nilotica* and *T. mossambica* showed little promise as weed control agents except for the control of filamentous algae. *T. heudeloti* did not feed appreciably on aquatic plants. *Carassius auratus* and *Ictalurus punctatus* when stocked at rates that would not interfere with other fish populations showed no potential for controlling aquatic weeds.

EVALUATION DES AVANTAGES RESPECTIFS DE HUIT ESPECES DE POISSON POUR LA LUTTE CONTRE LES PLANTES AQUATIQUES

Résumé

Des études ont été entreprises pour déterminer l'intérêt de certains poissons herbivores dans la lutte biologique contre la végétation aquatique. *Ctenopharyngodon idella* détruit une grande variété de mauvaises herbes lorsqu'il est introduit dans les étangs à raison de 49 à 99 par hectare. La carpe ordinaire, *Cyprinus carpio*, introduite à raison de 124 par hectare, détruit les algues filamenteuses et *Eleocharis acicularis*. Au cours de cette expérience, les carpes communes n'ont pas eu d'effets défavorables sur les autres poissons, même à effectifs plus élevés. *Tilapia melanopleura* déversé à raison de 2 470 à 4 940 par hectare s'attaque aux algues filamenteuses et à diverses plantes supérieures. Avec ces taux de peuplement, *T. melanopleura* ne nuit pas aux autres poissons. *T. nilotica* et *T. mossambica* n'ont pas donné de résultats prometteurs en tant qu'agents de lutte contre la végétation, sauf en ce qui concerne les algues filamenteuses. *T. heudeloti* ne semble guère apprécier les plantes aquatiques. Avec un taux de peuplement tel qu'il n'affecte pas les autres espèces de poisson, *Carassius auratus* et *Ictalurus punctatus* ne manifestent aucune aptitude pour le contrôle de la végétation aquatique.

EVALUACION DE ESPECIES ICTICAS ADECUADAS PARA LA ELIMINACION DE LAS MALAS HIERBAS ACUATICAS

Extracto

Se realizó un estudio para determinar el valor de los peces herbívoros en la lucha biológica contra las malas hierbas acuáticas. *Ctenopharyngodon idella* extirpó una gran variedad de malas hierbas cuando fue lanzado en estanques a razón de 49 a 99 indivíduos por hectárea. La carpa común *Cyprinus carpio*, cuando se pobló a razón de 124 indivíduos por hectárea, eliminó las algas flamentosas y *Eleocharis acicularis*. En este experimento, la carpa común no fue perjudicial para las poblaciones de peces cuando se pobló a razón de la densidad antes indicada. *Tilapia melanopleura* suprimió las algas filamentosas y una variedad de plantas superiores cuando se pobló a razón de 2.470 a 4.940 por hectárea. En esta proporción *T. melanopleura* no produjo efectos perjudiciales sobre otros peces. *T. nilotica* y *T. mossambica* ofrecieron pocas posibilidades como elementos para la lucha contra las malas hierbas en cuanto se refiere a la eliminación de las algas filamentosas. *T. heudeloti* no se alimentó en forma apreciable con plantas acuáticas. *Carassius auratus* e *Ictalurus punctatus* poblados en proporciones que no pudieran interferir con otras poblaciones ícticas, no mostraron posibilidades para la eliminación de las malas hierbas de los estanques.

1 INTRODUCTION

The control of undesirable plants in ponds is one of the major problems confronting fish culturists. Various methods have been employed with differing degrees of effort, cost and success. Recently the use of herbivorous fishes for weed control has met with much interest ; however, little extensive research has been conducted.

Since 1957 eight species of fish have been evaluated for effectiveness in aquatic weed control in more than 250 ponds and 300 plastic-lined and concrete pools at Auburn University Agricultural Experiment Station.

Objectives of this study were to determine (i) the effectiveness of *Ctenopharyngodon idella*, *Cyprinus carpio* (mirror strain of common carp from Israel), *Tilapia melanopleura*, *T. nilotica*, *T. mossambica*, *T. heudeloti*, *Carassius auratus*, and *Ictalurus punctatus* in weed control; (ii) weed preferences of fish; (iii) stocking procedures concerning size and numbers of fish; (iv) the effect of herbivorous fishes on other fish species in ponds; and (v) the economics of using herbivorous fishes for weed control.

2 REVIEW OF LITERATURE

2.1 *Ctenopharyngodon idella*

In early work Hoffman (1934) and Chen (1934; 1935) reported the food habits of *C. idella* and Lin (1935) presented the first comprehensive account of its life history. Food habits of *C. idella* were also reported by Lin (1946), Reich (1954), Hickling (1960), Verigin (1961), Hora and Pillay (1962) and Prowse *et al*. (1963).

Use of *C. idella* for weed control was reported by Araki (1943), Hata *et al*. (1949), Nakamura (1950), Aoki (1953), Nakamura *et al*. (1954), Wurtz (1960), Aliev (1963) and Anon. (1963). Nakamura *et al*. (1954) found addition of this species to ponds did not interfere with production of other fishes. Schuster (1952) recommended culture of *C. idella*, *Chanos chanos* and *T. melanopleura* for controlling aquatic weeds. *C. idella* was reported by Swingle (1957) as one of the most promising fishes for the control of rooted aquatics. Kuronuma and Nakamura (1957) suggested stocking 30 *C. idella*, weighing over 35 kg per ha for weed control. Alikunhi and Sukumaran (1964) found that 49 to 99 per ha effectively controlled weeds in four to eight weeks. Effectiveness of *C. idella* for weed control was reported by Avault (1965b) from preliminary work.

2.2 *Cyprinus carpio*

The food habits of *C. carpio* were discussed by Grafen von Maltzan (1935) who found that older carp were mostly bottom feeders and that young stages prefer plankton. Moen (1953a; 1953b) found that animal material predominated in the diet of *C. carpio*, but that green plant material was taken mostly by large carp. Wunder (1944), Rehder (1959), and Assman (1961) also reported food habits of *C. carpio*.

This species is not a true herbivorous fish, but has been reported as controlling weeds by Hogan (1946), Black (1946), Wunder (1949), Robel (1961), and Mathis (1965). Both Tryon (1954) and Threinen and Helms (1954) attributed weed control by carp through the mud-dying of waters with their feeding habits. Use of this species to control filamentous algae, especially *Pithophora* sp., was reported by Swingle (1957), Grizzell and Neely (1962), Shell (1962), and Avault (1965a).

2.3 Tilapia

Hofstede and Botke (1950) found that *T. mossambica* is principally a plankton feeder, but that adults consumed filamentous algae and higher plants. De Bont *et al.* (1950), Fish (1952), Blanc *et al.* (1955), le Roux (1956), Yashouv (1960), and McBay (1961) also discussed food habits of tilapia. McBay (1961) stated that 15 to 23 cm *T. nilotica* utilized *Pithophora* sp. extensively. Lowe (1955) and Hickling (1961; 1962) reported that *T. melanopleura* and *T. zillii* fed readily on aquatic plants. Chimits (1955; 1957) presented a comprehensive documentation of tilapia literature in a bibliography of 173 papers.

Use of tilapia for weed control has been reported by de Bont (1949), Hofstede (FAO/UN, 1955), Swingle (1957), Hee (1957), van der Lingen *et al.* (1960), Shell (1962), Timmons (1962), Pierce (1965), and Avault (1965a). Hee (1957) stated that prior to use of tilapia for weed control chemicals and labour cost $3,373 to $5,194 per year at the Kekaha Sugar Company in Hawaii. After using *T. mossambica* no expense was incurred except for the initial cost of $25.

2.4 Other species of fish

Various other species of fish have been reported as feeding on plant material including *Puntius javanicus* (Vaas and Sachlan, 1952; Ilan and Sarig, 1952; Hora and Pillay (1962a and b); *Osteochilus hasselti* (Vaas and Sachlan, 1952; Hora and Pillay, 1962a and b); *Carassius carassius* (Swingle, 1957); *Osphronemus olfax* (Villadolid, 1936; Hickling, 1961); and *Chanos chanos* (Rabanal and Montalban, undated). *P. javanicus*, *O. hasselti* and *O. olfax* which are tropical species, are unable to overwinter in temperate climates (Swingle, 1957).

Other species include *Alestes macrophthalmus* and *Distichodus* sp. (Hickling, 1961); *Archosargus probatocephalus* (Gunther, 1945); *Scarus* sp. and *Sparisoma* sp. (Schultz, 1958; Randall, 1961; 1965); *Hypophthalmichthys molitrix* (Verigin, 1961); *Mugil* sp. (Grizzell and Neely, 1962); *Ictalurus punctatus* and *Carassius auratus* (Avault, 1965a); and *Trichogaster pectoralis* (Thiemmedh, undated). Vaas (1953) lists 13 species of fish that are periphyton or vegetable feeders in West Borneo lakes on the Kapuas River.

3 MATERIALS AND METHODS

3.1 Technique for evaluating weed control

A sampling apparatus devised by E. W. Shell was used to determine weeds quantitatively and qualitatively. This consisted of a bait casting outfit with a 30 g lead sinker to which four soft wire hooks were attached. A slip-float was placed on the line above the hook-bearing weight.

When the weight was cast into the pond it sank to the bottom leaving the float at the surface above it. The reel handle was then turned slowly several times, drawing the weight across the bottom and allowing it to collect weeds. After the hooks had been dragged along the bottom for 2 to 3 m, the rod was given a short jerk. The weight was raised from the bottom and held under the float, thereby ending the sampling at that station. The line was then reeled in rapidly to keep the weight off of the bottom. The species and abundance of weeds were recorded. Duplicate samples were taken at 3, 10 and 25 m from shore at each sampling station. Several samples were taken from approximately one-fourth of the pond's margin.

3.2 Pond experiments

Field tests consisted of stocking a potentially herbivorous fish at various rates per ha into a pond containing higher aquatic plants or filamentous algae and observing if there was a change in weed abundance. Most of the ponds stocked were privately owned and contained established populations of bluegill, *Lepomis macrochirus* and largemouth bass, *Micropterus salmoides*. Tests were also conducted in Auburn experimental ponds. These ponds were drained at the end of the experiments to determine survival and composition of the fish populations.

Qualitative and quantitative observations of weeds were made at the time of stocking and periodically thereafter. Occurrence of plankton blooms and turbidity were also recorded. Fish samples were periodically obtained by seining in many of the ponds to determine the effect of added fish on the pre-existing population.

3.3 Pool experiments

Plastic-lined pools (2.7 m in diameter and 0.9 m deep) and concrete pools (2.7 m x 6 m) with a bottom of 10 to 15 cm topsoil and clay subsoil were filled with well water. Aquatic plants were planted either as single species or in combination of species in pools to simulate a pond with a heavy infestation of weeds. Different species of fish were then stocked at various numbers per ha. The abundance of weeds was recorded at the time of stocking and at one or two week intervals thereafter. Weed abundance was estimated visually and recorded on the basis of the percentage of the total pool area. Observations on weed preference of the fishes, plankton blooms and turbidity were recorded.

4 RESULTS AND DISCUSSION

4.1 Ctenopharyngodon idella

4.1.1 Pond experiments

C. idella, 25 to 40 cm in total length, were stocked at rates of 49, 74 and 99 per ha in ponds heavily infested with weeds. Excellent control was obtained in one to three months of the following weeds: Chara sp., Potamogeton diversifolius, Eleocharis acicularis, and Rhizoclonium sp.

In one pond C. idella virtually eliminated an extremely heavy infestation of E. acicularis in less than three months when stocked at 74 per ha. The weed was clipped off as if it were grazed. After eliminating this weed, C. idella readily ate Eichhornia crassipes, when it was placed in the pond within a floating frame.

None of the ponds became muddy or developed phytoplankton blooms as a result of feeding activities of C. idella, but in some ponds a brown organic stain developed, probably from faecal wastes.

C. idella appeared to prefer pelleted fish feed to aquatic weeds in two holding ponds. When fish were fed 3 percent of their body weight per day, Chara sp. invaded one pond and E. acicularis invaded a second and increased in abundance. When feeding was discontinued the fish in both ponds began eating weeds and eventually eliminated them.

4.1.2 Pool experiments

Previous tests (Avault, 1965b) revealed that 25 to 30 cm C. idella when stocked at the rate of 1,693 per ha in plastic-lined pools eliminated within two to three weeks Najas guadalupensis, P. diversifolius, Elodea densa, Chara sp., Spirodela polyrhiza, Utricularia biflora, E. acicularis, Vallisneria americana, and Pithophora sp. After elimination of these weeds, there was an interim of two to three weeks during which the fish discontinued feeding. Following this period Alternanthera philoxeroides, Myriophyllum brasiliense, M. spicatum, and E. crassipes were eaten and finally eliminated within an additional two weeks. None of the pools became muddy even at the high stocking rate of 1,693 per ha, but a dark organic stain developed in most pools.

At the end of the experiment all the pools were drained and the fish removed. In most pools no trace of vegetation could be found. The pools were refilled with water and allowed to stand. The following spring P. diversifolius and E. acicularis reappeared in some of the pools.

C. idella approximately 25 cm long were stocked in concrete pools at a rate of 494 per ha. Within one to two months the fish virtually eliminated *Chara* sp., *N. guadalupensis*, *P. diversifolius*, *Bacopa rotundifolia*, *E. densa*, *E. acicularis* and *Pithophora* sp. In two pools where complete control was apparent the fish were removed. Within one month *Chara* sp. and *E. acicularis* reappeared. *A. philoxeroides*, *M. brasiliense* and *E. crassipes* were controlled in some pools but not in all.

Most of the pools developed a brown organic stain. Chemical analyses of water revealed a 300 percent increase in potassium content but none in sodium, nitrogen or phosphorous.

Preference by *C. idella* for certain species of weeds was observed in pool and pond experiments. Additional tests were conducted in aquaria. *C. idella* were offered equal amounts of various combinations of weeds and the preference recorded; there was some overlap, especially among the more preferred species. The following plants are listed in decreasing order of preference: (i) *Chara* sp., (ii) *N. guadalupensis*, (iii) *P. diversifolius*, (iv) *E. acicularis*, (v) *Ceratophyllum demersum*, (vi) *B. rotundifolia*, (vii) *E. densa*, (viii) *M. spicatum*, (ix) *V. americana*, (x) *E. crassipes*, (xi) *M. brasiliense*, and (xii) *A. philoxeroides*.

4.2 *Cyprinus carpio*

4.2.1 Pond experiments

Common carp, 15 to 25 cm in total length, were stocked at a rate of 124 per ha in ponds containing bluegill, *Lepomis macrochirus* and largemouth bass, *Micropterus salmoides*. The common carp were effective in reducing or eliminating *Pithophora* sp., *Rhizoclonium* sp. and *E. acicularis* but in some ponds two to three years were required for control. Best control was obtained in ponds that developed phytoplankton blooms.

The long period of time required for control in some ponds appeared to be due to stocking small fish, which had to attain a sufficient size before utilizing plant material and becoming bottom feeders. Control was attributed both to feeding on the weeds and to silting of the weeds caused by feeding activities. When carp were stocked at 62 per ha, variable results were obtained. Failures were attributed to poor survival.

In all cases where control of filamentous algae and *E. acicularis* was obtained, the carp were in sufficient numbers for some to be caught by fishermen. When stocked at 62 or 124 per ha, this fish rarely spawned in ponds that contained an established population of other fish species. None of the test ponds became muddy.

Carp, 15 to 25 cm in total length, stocked in bass-bluegill ponds at rates of 62 to 124 per ha, failed to control *E. densa*, *Nymphaea* sp., *Brasenia schreberi*, *Chara* sp., *Hydrocotyle umbellata*, *N. guadalupensis*, *B. rotundifolia*, *S. polyrhiza* and *Hydrochloa* sp.

In bass-bluegill ponds stocked with fingerling carp at more than 124 per ha little benefit in weed control was obtained. Predation by largemouth bass appeared to account for the failures as few carp survived.

In ponds stocked only with common carp, submersed aquatic plants were always eliminated. In these ponds the carp spawned, and as a result large numbers of individuals were present. Under these conditions fish usually stirred sufficient silt to make the ponds muddy.

Mortality of carp was the main limiting factor to their use in weed control. Mortality was attributed to: (i) loss of carp during flooding, (ii) removal by fishing, (iii) natural mortality, and (iv) predation by largemouth bass.

Common carp frequently escaped from ponds during periods of high water. In one pond an estimated 50 percent of the population was lost. Carp were caught readily by fishing, but most fishermen were encouraged to return the fish to the ponds. Very few fish were removed by fishing from most ponds.

Experiments have shown that natural mortality of common carp was approximately 20 to 30 percent annually. Ponds in which control of algae was obtained remained algae-free for about three or four years. At the end of this time most of the carp had died and restocking was necessary.

Fingerling carp are highly susceptible to predation by largemouth bass. In three ponds the mortalities were 95 percent within one month, 77 percent within 12 months, and 87 percent within 29 months. Stocking with larger carp, 20 to 40 cm in length, resulted in better survival in two bluegill brood ponds. After 84 days one pond was drained and 18 of the 20 carp were recovered. The second pond was drained 99 days after stocking and all the 20 carp were recovered.

A bass-bluegill pond was stocked with 15 to 25 cm carp at a rate of 62 per ha. Eight months later the pond was drained and 82 of 87 carp stocked were recovered. Of the 392 bass in the pond at the time of draining, 51 were 35 to 45 cm in length. However, even a 45 cm largemouth bass can swallow only 18 cm or smaller _Carassius auratus,_ and common carp have greater body depths than _C. auratus_.

The fish population of the above pond was analyzed to determine the effect of carp on the bluegill population. Since common carp are forage fish, any effect on the population would show as competition between carp and bluegills. On draining, 439 kg of bluegills per ha were recovered. This was one of the highest weights of bluegills produced at this station in a bass-bluegill pond. Thus there was no apparent competition between the 439 kg of bluegills per ha and the 133 kg of carp per ha. In other ponds also similar results were obtained. Weights of carp used for weed control did not measurably reduce growth of bluegills or interfere with the pond balance.

4.2.2 Pool experiments

Common carp, approximately 15 cm long, when stocked at the rate of 1,693 per ha in plastic-lined pools gave good control of _Pithophora_ sp. and _E. acicularis_ within three months. Partial control was obtained on _N. guadalupensis_ and _P. diversifolius_. These two weeds were reduced as much as 50 percent within three months. No appreciable control of _Chara_ sp., _E. densa_, _A. philoxeroides_, _M. brasiliense_, _M. spicatum_, and _V. americana_ was obtained.

Control over _E. acicularis_ appeared to be the result of uprooting by the carp rather than actual ingestion of the weed, even though it was present in their stomachs. _E. acicularis_ has a rather short root system and is apparently uprooted easily since it could be seen floating in pools.

In one plastic pool test where carp were stocked at a rate of 1,693 per ha the water remained clear in 12 pools, became dingy in 14, developed a phytoplankton bloom in four and was muddy in 10 pools. The eight control ponds that received no carp were clear but in four of the pools higher plants were densely tangled with filamentous algae. They did not occur around higher plants in pools with carp.

Feeding activities of common carp left small holes or pock marks in the bottom of many pools. These marks were observed in over 90 percent of all pools where some reduction of weed abundance occurred. The pock marks were about 3 to 7 cm deep and wide. In some pools the holes were so numerous that a honeycomb effect was achieved. It was also noted at draining that in most pools the weeds were covered with silt. Moreover, in weed preference studies in aquaria, carp were frequently observed to work over the bottom by sucking up and spitting out the substratum.

Weed preferences were observed in pools and in tests conducted in aquaria. Filamentous algae were preferred. _Chara_ sp. and higher plants were fed on in aquaria but appeared to be eaten only because little else was available.

4.3 Tilapia

4.3.1 Pond experiments

T. melanopleura, 18 to 13 cm in total length, when stocked in April and May at 2,470 to 4,940 per ha in established bass-bluegill ponds, appreciably reduced or controlled the following weeds within three to four months: *Pithophora* sp., *Spirogyra* sp., *E. acicularis*, *E. densa*, *Hydrochloa* sp., *U. biflora*, *Rhizoclonium* sp., *M. brasiliense*, *S. polyrhiza*, *P. nodosus*, *Chara* sp., *Micranthemum umbrosum*, and *N. guadalupensis*. Under the same stocking conditions *T. melanopleura* failed to control *B. schreberi* and *Nymphaea* sp. In some ponds in which the water remained clear the weeds reappeared the following year.

In a 7.3 ha lake 13 to 18 cm *T. melanopleura* were stocked in April at 617 per ha and effectively reduced a heavy infestation of *N. guadalupensis* that had been a problem for more than six years. Seining in August revealed numerous intermediate sunfishes with small tilapia present in lesser numbers. In other ponds where weeds were controlled, small tilapia were also abundant (10 to 30 per 15 m quadrant seine haul). This and the presence of tilapia spawning beds were indications of good survival. In ponds that contained many large bass, survival of tilapia and weed control were usually poor.

Stocking with young-of-the year *T. melanopleura* did not prove successful since too little time was available for weed control. In Alabama this species of tilapia usually begins spawning in May, and 8 to 10 cm young are not available until August. Stocking in August did not allow enough time for weed control before cold weather killed the fish.

Generally, the best means for controlling aquatic weeds in ponds in the United States is with fertilization. However, in many experimental ponds, the weed growth was so heavy or water flow through ponds so great that fertilization was impractical. In these cases use of *T. melanopleura* appears feasible. Once weeds are reduced or controlled, the ponds may be fertilized to encourage phytoplankton blooms to shade out remaining weeds. On the other hand *T. melanopleura* may give only temporary control of weeds unless restocked each spring in temperate climates. In this case a herbivorous fish that can overwinter in ponds is needed.

T. melanopleura stocked in farm ponds for weed control experiments has had no adverse effects on the fish population. When stocked in established bass-bluegill populations at the rate of 1,235 per ha, almost no young-of-the year fish became large enough to utilize plant material. Either some repressive factor present prevented the fish from spawning, or bass and bluegill eliminated the young fish shortly after hatching. In newly stocked ponds brood tilapia often produced larger numbers of young, when spawning took place before bluegill spawning. However, if bluegills spawned first, the tilapia produced few young. Stocking 2,470 or 4,940 tilapia per ha had no adverse effects on pond balance.

T. melanopleura have not interfered with growth of other fish species when stocked in large impoundments that contained established populations of largemouth bass and bluegill (Byrd and Crance, 1965). They reported that tilapias did not contribute a significant amount to the average total catch during a 14 year study because they were stocked only once in most lakes and did not overwinter. They found, however, that the stocking of 10 to 13 cm tilapias at the rate of 2,470 per ha in two lakes provided an average catch of 58 kg per ha during a four month period with no significant effects on the other species in the population.

Results with *T. nilotica* and *T. mossambica* for weed control have been less encouraging than those with *T. melanopleura*. *T. nilotica* has controlled *Pithophora* sp., and *N. guadalupensis* in ponds when stocked at 2,470 to 4,940 per ha, but showed little promise for controlling most higher plants. *T. mossambica* has also been effective in controlling *Pithophora* sp. in ponds, but has not been effective in controlling higher plants. For example, in two experimental ponds containing 7,410 *T. mossambica* per ha with no other fish species present, *Chara* sp., and *E. acicularis* invaded and covered 50 to 70 percent of the pond bottom by fall draining.

4.3.2 Pool experiments

Ten to 15 cm long T. melanopleura, T. nilotica, T. mossambica and T. heudeloti were stocked in plastic-lined pools at rates of 3,384, 5,076, and 6,768 per ha. At rates of 5,076 and 6,768 per ha T. melanopleura gave excellent control of the following weeds within 80 to 90 days: N. guadalupensis, P. diversifolius, E. densa, Chara sp., S. polyrhiza, U. biflora, E. acicularis and Pithophora sp. However, no apparent reduction was obtained in E. crassipes, A. philoxeroides, M. brasiliense, M. spicatum and V. americana. These weeds were eaten but not until other weeds were eliminated. Six months after T. melanopleura was removed from the pools some weeds reappeared. Morever, viable akinetes of Pithophora sp. were recovered from tilapia faeces and germinated in water.

Both T. nilotica and T. mossambica were effective in controlling Pithophora sp. T. mossambica failed to reduce higher plants, whereas T. nilotica reduced N. guadalupensis, P. diversifolius, and E. acicularis in some pools but failed to reduce these weeds in other pools. T. heudeloti fed on higher plants in pools, but no extensive reduction was obtained.

T. melanopleura showed less selectivity in feeding (on weeds) than C. idella. Weeds eaten in order of preference were: (i) N. guadalupensis, (ii) P. diversifolius and Chara sp., (iii) E. acicularis, (iv) C. demersum, (v) E. densa, (vi) B. rotundifolia, (vii) M. spicatum, (viii) V. americana, (ix) M. brasiliense, (x) E. crassipes, and (xi) A. philoxeroides.

4.4 Other species of fish

Ictalurus punctatus reduced or eliminated Pithophora sp. in ponds when stocked at the rate of 2,470 per ha, but not when stocked at 494 per ha. When stocked in pools at 1,692 per ha, they fed only slightly on higher plants. The weeds appeared to be eaten only when little else was available.

Carassius auratus controlled Pithophora sp. when stocked in pools at 1,692 per ha but did not reduce the abundance of higher plants.

5 SUMMARY AND CONCLUSIONS

The ideal herbivorous fish for aquatic weed control should meet the following requirements: (i) control a wide variety of weeds, (ii) not interfere with other fish species, (iii) be hardy and easy to handle, (iv) be economical to use, and (v) add to the fishery.

5.1 Ctenopharyngodon idella

(i) C. idella 25 to 40 cm long, when stocked at 49 to 99 per ha controlled a wide variety of weeds. Stocking rates should be determined according to the species and abundance of weeds. The lowest stocking rate at which weeds are still controlled is recommended.

(ii) This fish is currently being evaluated for its effect on bass-bluegill populations. Other studies (section 2.1) indicate that C. idella has not interfered with other fish species.

(iii) C. idella is hardy; it can withstand cold water, low oxygen and frequent handling.

(iv) This species will grow rapidly and efficiently on a wide variety of foods. Since only small numbers are needed for weed control in ponds, it should be inexpensive to use. Spawning, once a limiting factor in the use of this species, has been induced by hormone injections (Tang, et al., 1963; Alikunhi et al., 1963; Alikunhi and Sukumaran, 1964; Lin, 1965)

(v) C. idella should add to the fishery of a pond both by its weight and by reducing weeds.

Perhaps the only real limiting factor for use of C. idella in the United States is that it is an exotic fish and its escape and possible establishment in our river systems must be considered. Only through long experimentation and investigation can the advantages and disadvantages of the introduction be evaluated. This problem might be solved by use of mono-sex culture.

5.2 Cyprinus carpio

(i) Common carp controlled few species of weeds when stocked in bass-bluegill ponds at 124 per ha, but its control of Pithophora sp.alone merits its use, since this branched alga is a major problem in the southeastern United States.

(ii) This fish has not interfered with other species of fish when stocked at 124 per ha.

(iii) Common carp are hardy, easy to handle and overwinter easily.

(iv) There are commercial dealers in the United States selling carp for weed control at 10 to 50 cents a piece depending on size. The cost varies from $12.50 to $61.75 per ha for their use in algae control.

(v) Common carp add little to the catch in ponds but do have considerable angler appeal, especially when individual fish reach 4.5 to 5.4 kg in size.

5.3 Tilapia

(i) T. melanopleura when stocked at 2,470 to 4,940 per ha controlled a variety of weeds. Best control was obtained in ponds where survival was high and the fish spawned. After tilapia reduced weed abundance, fertilization was effective in further control.

(ii) T. melanopleura has not interfered with other fish species in large impoundments or in farm ponds.

(iii) T. melanopleura rarely overwinter in Alabama. They begin dying when the water temperature reaches 12°C.

(iv) Consequently, at this station they have been overwintered each year in troughs in a heated building for the following year's research. The expense of overwintering the fish is the major limiting factor for use of tilapia in most of the United States. They have been overwintered in springs, but survival has often been poor.

(v) T. melanopleura when stocked at 2,470 to 4,940 per ha have not appreciably added to the fishery. However, late summer fishing, when other fishing declines, has often been good. The sunfish-like characteristics of this exotic fish contribute to its angler appeal.

T. mossambica and T. nilotica controlled some aquatic weeds, but T. melanopleura was more efficient than these two species which do not merit further consideration. T. heudeloti fed on aquatic weeds but not appreciably.

5.4 Other species of fish

Carassius auratus and Ictalurus punctatus when stocked at rates low enough to prevent interference with other fish species had little potential for controlling weeds.

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NEW SYSTEMS AND NEW FISHES FOR CULTURE IN THE FAR EAST

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NEW SYSTEMS AND NEW FISHES FOR CULTURE IN THE FAR EAST

Abstract

The paper deals with the newly developed systems of warm-water fish culture observed in the Far East Asia, and pond culture of fishes considered new to the region. The topics reviewed here are by no means new in the chronological sense, but are highly significant in successful development of fish culture. A survey is attempted of the problems of hormone-induced spawning of Chinese carps, which will eventually result in marked changes in the existing methods of spawn collection and rearing.

The culture of new varieties of common carp appears to have great potentialities in increasing the productivity of existing carp ponds in this region of Asia. The tilapia might be called a newcomer to the region, but its poor resistance to lower temperature of water restricts its spreading to the north in this region. The hybridization of tilapia species and the crossing of carp and goldfish as well as intergeneric hybridization of Chinese carps are reviewed.

NOUVELLES TECHNIQUES DE PISCICULTURE ET NOUVEAUX POISSONS EN EXTREME-ORIENT

Résumé

Cette communication traite des nouveaux systèmes de pisciculture en eau à température élevée pratiqués en Extrême-Orient ainsi que de l'élevage en étang de poissons considérés comme nouveaux dans la région. Les sujets passés en revue sont loin d'être nouveaux à proprement parler, mais présentent un intérêt particulier pour le développement satisfaisant de la pisciculture. L'auteur a tenté de cerner les problèmes que pose l'utilisation des hormones pour provoquer la fraye de la carpe chinoise, technique qui pourrait entrainer de profonds changements dans les méthodes actuelles de recueil et d'élevage du frai.

L'élevage de nouvelles variétés de carpes communes paraît ouvrir des perpectives fort intéressantes pour l'accroissement de la productivité des étangs existants dans cette région de l'Asie. Le Tilapia peut être considéré comme un nouveau venu dans la région, mais sa faible résistance aux basses températures de l'eau impose des limites à son expansion dans le nord de la région. L'auteur traite également de l'hybridation de l'espèce Tilapia, du croisement de carpes et de poissons rouges et enfin l'hybridation intergénérique de carpes chinoises.

NUEVOS SISTEMAS Y NUEVOS PECES PARA CULTIVO EN EL LEJANO ORIENTE

Extracto

El trabajo se ocupa de los sistemas de piscicultura en aguas cálidas recientemente desarrollados en el Lejano Oriente asiático y el cultivo en estanques de peces considerados nuevos en la región. Las cuestiones examinadas no son en modo alguno nuevas en el sentido cronológico pero tienen gran importancia en el desarrollo con éxito de la piscicultura. Se intenta un exámen de los problemas del desove inducido de carpas chinas con hormonas que, en último término, podrá determinar cambios sensibles en los métodos actuales de recogida de las masas de huevos de la freza y en el cultivo de su producción.

El cultivo de nuevas variedades de carpa común parece contar con grandes posibilidades para elevar la productividad de los actuales estanques de carpa en esta región de Asia. La tilapia podría considerarse como nueva en la región, pero su escasa resistencia a la menor temperatura del agua restringe su difusión hacia el norte de esta región. Se analiza la hibridación de especies de tilapia y el cruzamiento de carpa y pez dorado de la China, así como la hibridación intergenérica de carpas chinas.

1 CARP CULTURE IN FLOATING NET-CAGES IN LAKES

1.1 Status and history

Fish culture in cages has been practised in Cambodia and Java, though not on a large scale. In both countries the feeding of the fishes in cages is not intensive, but still appreciable quantities of fish are produced from small areas (Hickling, 1962).

In Japan common carp (Cyprinus carpio) culture is one of the oldest traditions, and fish farmers have developed various techniques. Carp culture in net-cages floating on the lake surface was first attempted in 1951 at the Miyazaki Fisheries Experiment Station, Kyushu and produced 11.3 kg of fish per m^2 within 85 days by intensive feeding. Since then fisheries stations in a number of prefectures (south of middle Honshu and Kyushu), stimulated by the successful experiment in 1951, have experimented with it using common carp, rainbow trout (Salmo gairdneri) and the ayu (Plecoglossus altivelis). The advantages of net-cage carp culture are its low cost of investment compared with ordinary fish ponds constructed on land, and the ease with which sites may be found to practise it, for the net-cages may be used in any type of standing water; lake, swamp, farm-pond or reservoir provided that there are no high waves.

The development of this method has also been stimulated by the fact that in the impounded waters which have been created recently in great numbers everywhere in the country, fishing operations are severely restricted by the bad bottom conditions, while the net-cage fish culture can produce the carp, which is the most valuable fish species available in reservoirs, by investing the small amount of money which local people can afford and by learning ordinary fish culture techniques. The successful culture of sea fishes (yellow-tail, porgy, puffer, etc.) in floating net-cages, which has been practised along the coast especially of the Seto Inland Sea, has also helped to hasten the development of carp culture in cages. The technique has not yet reached its highest efficiency, and further investigations are needed, especially on the construction of cages, rates of fish stocking, feeding, etc., which all depend upon adequate knowledge of the physiology of the fish in relation to the limnological environment surrounding the cage.

1.2 Construction, management and harvest

The design and construction of the net-cages are by no means new because skipjack angling boats in many fishing ports along the Pacific coast of Honshu, Shikoku and Kyushu use live sardines as bait, and these are kept in shallow net-cages floating on the sea. The net-cage used for carp culture is only a modification of the sardine net-cage used for more than half a century. Basically the net-cage is a flat-bottomed net which has the top open on the water surface. The netting is shaped by bamboo sticks into a square or other desired shape, and is kept afloat by a number of steel drums. The net-cage thus prepared is tied by wires to four (in the case of a square net) heavy wooden stakes driven into the lake bottom. Usually a low wing net is attached all around the upper rim of the net-cage to prevent the fish jumping out.

The dimension of the net-cage varies from seven m^2 to as large as 81 m^2 in surface area, but the net is usually about 2 m deep so that it can be placed near the shore in water 3 m deep, the depth found to be most satisfactory for a number of reasons - such as for setting the net, carrying out culture operations, and safety of construction etc.

The actual production of carp in the net-cage, as in any other type of fish culture, varies with the conditions. An evaluation of fish culture by this method, made on the basis of fish weight gained per unit of surface area of water and per unit of time, is presented in Table III, from which it can be seen that fish production in these net-cages stands second only to that in running water pond culture.

Table I

Record of carp culture in net-cages showing the details of management from stocking to harvest and the amount of food given in 16 cases of the culture conducted in seven lakes and one river in Japan, 1963. Data compiled by Nagano Prefecture Fisheries Guiding Station, Suwa Branch (1964).

Case		A	B	C	D	E	F	G
(i)	Surface area (m^2)	19.4	49	49	25	25	13.2	13.2
(ii)	Period (days)	91	156	119	90	85	85	85
(iii)	No. of fingerlings stocked	1571	832	2405	1700	435	450	320
(iv)	No. of fish harvested	1547	466	1919	1580	409	410	301
(v)	Weight of fingerlings stocked (kg)	173	75	148	111	85	67	54
(vi)	Weight of fish harvested (kg)	875	341	1034	567	172	316	252
(vii)	Gain in weight (times)	5	4.6	6.9	4.1	2.0	4.7	4.7
(viii)	Production (kg/m^2)	45	7	21	23	7	24	19
(ix)	Total weight of food given (kg)	1090	594	1799	745	215	380	310
(x)	Food conversion	1.5	2.2	2.0	1.6	2.5	1.5	1.6

	H	I	J	K	L	M	N	O	P
(i)	7.2	81	81	81	81	81	81	9	9
(ii)	98	147	123	152	136	158	62	93	93
(iii)	450	4000	3400	4000	3900	4900	960	700	300
(iv)	410	3430	3050	3270	3590	4220	846	675	295
(v)	45	290	300	290	200	230	180	82	33
(vi)	320	2712	2560	2385	2404	3089	480	219	96
(vii)	7.1	9.4	8.5	8.2	12	13.4	2.7	2.7	2.9
(viii)	44	34	32	30	30	38	6	24	11
(ix)	290	3565	3199	3060	3055	4044	528	210	90
(x)	1.1	1.5	1.4	1.4	1.4	1.4	1.8	1.5	1.5

Records of carp produced in relation to management (stocking rate and food given) from 16 such net-cages in 1963 are given in Table I. The data are still too scanty to make conclusive statements, but suggest that larger nets, if it is possible to make them, and longer periods of operation (if feasible without risking a temperature drop) will result in the higher production of fish. Further experiments are required to develop this technique for more extensive adoption.

1.3 Economy

To illustrate the economy of net-cage carp culture, results from one of the most successful experiments, made at Lake Suwa, Nagana Prefecture, by the Prefecture Fisheries Station in 1952, are given in Table II. Six net-cages, three of 81 m^2 and three of 29 m^2, all 2.1 m deep, were stocked with 1.41 ton of fingerlings in the latter part of May. Feeding started 1 June. By the end of October, 9,445 kg of fish were harvested. Such a net-cage can be used for three years.

Table II

Balance sheet of rearing 10 ton common carp in floating net-cage placed in lake water (Nagano Prefecture Fisheries Guiding Station).

EXPENDITURE:	
Facilities..........Yen	90,500
Fingerling (1.41 ton)..........	423,500
Feed (13.1 ton)..........	732,000
Electricity, fuel etc..........	45,964
Wages (2 men for 110 days and others)..........	134,000
Tools	3,000
Repair of cages..........	78,000
Occupation fee of water area..........	15,000
Rent of land..........	1,000
Miscellaneous..........	5,000
Interests on money borrowed	28,175
Total..........	1,555,259
INCOME :	
Fish harvested 20 August and 5 and 20 September weighing 7,264 kg...	1,524,000
The same on 20 and 30 October weighing 2,181 kg..........	414,000
Total (9,445 kg)..........	1,919,000

The net gain in fish weight was 8,035 kg, for which 13,100 kg food was consumed. Twenty nine kg fish were produced in 1 m^2. The mortality of carp during the five month period was 10 percent.

The advantage of the net-cage system is evident in the highly economical utilization of water area, and that the amount of water required does not come into consideration. Usually there is no shortage of dissolved oxygen required by the fish unless an excessive stocking rate is used.

1.4 Per unit production of carp in Japan

To compare the production of common carp by different systems Chiba (1965) compiled data on the production figures calculated in four different units (Table III), so that the per unit production of different methods could be compared. The figures in this table allow comparison of the efficiency of each system. For instance, if made on the basis of gain in fish weight per unit surface area of water used and per unit of time spent, it is clear that the production of carp per m^2 of surface area in net cages stands second only to that in running water fish ponds, but surpasses all other systems adopted in Japan.

However, the use of such systems cannot be evaluated on such figures alone, because each culture method is made possible only by the conditions that permit or demand its adoption. As Prowse (1963) pointed out, it is not enough to transfer a system from one area to another with completely different environmental requirements. The net-cage system cannot be practised because of its high efficiency unless environmental conditions are well suited for its operation.

Table III

Comparison of production (kg/m^2 or kg/m^3) of common carp in different types of culture in Japan. Data were compiled under the premises that the depth of water is 2 m; there is no change of water in standing water ponds, and the culture starts with the stocking of 70 g fingerlings and lasts 200 days (After Chiba, 1965).

System	Pond area (kg/m^2)	Volume of water (kg/m^3)	Total volume of water used (kg/m^3)	Net gain in weight (Times)
Standing water				
Farm-pond (no feeding)	0.01-0.15	0.005 - 0.08	0.005 - 0.08	———
Farm-pond (with feeding)	0.1 - 0.5	0.05 - 0.25	0.05 - 0.25	6 - 11
Fish pond	0.4 - 0.8	0.2 - 0.4	0.2 - 0.4	7 - 10
Running water				
Net-cage	7 - 68	3.5 - 34	———	8 - 13
Fish pond	60 - 190	30 - 95	0.0005 - 0.001	10 - 15
Recirculating tank	11 - 33	4 - 15	0.8 - 1.9	- 6

2 CARP CULTURE IN RECIRCULATING TANKS

2.1 Characteristics and status

The efficiency of fish culture is increased by minimizing the size of pond and thus cutting down the wages of labourers. This can be accomplished only if the fish are fed extensively by hand, but not if they are left to use natural food organisms for their maintenance and growth. By recirculating the water in a small tank in which fish are reared it is possible to economize the extent of the facility and amount of water used. The principle underlying this is by no means new, but has been adopted by almost all the aquaria anywhere in the world. The only difference found between aquarium and fish culture tanks is the heavy stocking rate and the extensive feeding in the latter. In this system the same water is circulated from fish tanks to filtration tanks and back to fish tanks again, using the water head between the tanks and pumping up from lower to higher levels of water. The crowded fish stock in a limited space means that the physiological demand of the fish, especially in respiration and excretion, must be taken care of by every possible means in the construction of the system, filtration apparatus and water circulation, as well as in the operation of the whole system. In practice, the respiration problem is solved by the aeration of water, and the "purification" of water is accomplished by filtration through coarse sand or gravels. The present system, which may be termed "intensive fish culture" resembles the so-called running water fish culture in ponds, but is basically different in the amount of water used. This is the point where the fish respiration and excretion bring in critical problems which determine the potential of the whole operation.

Carp culture in recirculating water was put into commercial operation in 1951 by Mr. Motokawa, a fish culturist in Maebashi City, in Central Japan. Later, the same system was tried for the culture of the common eel (*Anguilla japonica*) and the ayu (*Plecoglossus altivelis*) at some fisheries stations in the country. The present system, however, has not been accepted as a popular practice, probably because of the high initial cost of building and the need for highly trained technicians.

2.2 Background research

To trace the development of the system into commercial fish culture, it is necessary to appraise the painstaking research carried out by Dr. A. Saeki, Fisheries Faculty, Tokyo University. In his series of experiments lasting more than a decade, Saeki studied the physiology of fish in recirculating water and chemical changes in the water as well as mechanical details of tanks, filtration apparatus and circulation system. Bacteriological studies were also made of the filter and the water, and his test fishes included carp, goldfish (*Carassius auratus*), eel, trout and some molluscs. This research provided a general rule concerning the relationship between the amount of water required, size of filter and the number of fishes, which is summarized in Table IV. These figures are only of general significance, because various factors involved in cultivation (size and number of fish stocked, temperature of water, nature and amount of food given, etc.) are intimately associated with the amount of water in the tank, speed of water circulation and of filtration. For example, the total space of facility will be 12 to 21 times and the amount of water 6 to 15 times that of the fish, then, the fish will occupy 8 to 5 percent of the total space and 16 to 6 percent of the water. The entire water supply has to be circulated every two hours (in a large outfit) or every half hour (in a smaller outfit). To determine the rate of stocking Saeki suggests that if fish growth is the objective, carp fingerlings amounting to 30 to 70 percent of total fish holding capacity should be stocked, while only holding fish in the tank will allow a stocking rate of 200 percent of the holding capacity.

2.3 Actual operation and evaluation

Several fish rearing tanks have been made in the country along such lines, among which one example given below will explain some details of its structure and operation for the production of common carp. In 1951 Mr. I. Motokawa at Maebashi City, with the technical help of Dr. Saeki built a one-ton tank converted from an ordinary concrete fish pond. The details were as follows:

Dimensions:

Fish tank --- 76.5 m^2, 1.3 m deep

Filtration tank — 24.8 m^2, 1.9 m deep

Volume of filter — 9.2 m^3 (gravel of diameter 1.5 cm)

Head of the two tanks — 1.7 m

Total volume of water — 205 m^3

Table IV

The relationships between weight of fish and volume of water and filter required for fish culture in recirculating water system, proposed by Dr. A. Saeki. After Kawamoto (1965).

	Weight	Volume or space	Volume of water
Fish cultured	a	a	----
Capacity of tank	1 - 10 a	1 - 10 a	1 - 10 a
Volume of filter (2-5 mm sand)	30 a	10 a	5 a
Total volume	32 - 41 a	12 - 21 a	6 - 15 a
Fish in percent of the total	3 - 2.5	8 - 5	16 - 6

Table V

Records of carp culture in one-ton and five-ton water recirculating systems, with main features of their capacities. An experimental operation by Mr. Motokawa. After Deguchi (1965).

	One-ton	Five-ton
Total volume of water (m^3)	205	286.3
Volume of water circulation (m^3/h)	75	135
Oxygen intake (l/h)	2.4	3.5
Fish tank		
Surface area (m^2)	76.5	125.1
Depth (m)	1.3	1.5
Filtration tank		
Surface area (m^2)	24.8	47.6
Volume of filter (m^3)	9.2	28.6
Fish harvested (ton)	0.85	4.12
Fish harvested in unit area (kg/m^2)	11.1	30.3
Period (days)	55	57
Temperature of water (°C)	16.3-27.0	17-27.0
Number of fingerlings stocked	1,216	4,370
Weight of fingerlings stocked (kg)	543	2,250
Food given (kg)	625	1,890
Number of fish harvested	1,182	4,308
Weight of fish harvested (kg)	852.2	4,121
Number of fish died	34	62
Weight increase (percent)	57	83
Food conversion	2.02	1.01
Average increase of weight (g)	273	442
Same per day (g)	5.35	7.75

Working capacity:

Working area of filtration — 15 m^2

Filtration rate — 102 m a day

Pumps — one 2 kw centrifugal and one 2 kw vertical;
one 5 HP gasoline engine (for emergency)

Circulation of water — 75 m^2 per hour

Working oxygen intake — 220 l a day

Filtration — 830 g a day as N

Carp reared — up to one ton

Carp held — up to six tons

In addition, a pump-room and piping need further space, and a concrete pond located next to the facility was used as a sedimentation (or reservoir) tank. The water was run 75 m^3 in one hour from fish tank to sedimentation tank, then, through pipes, to pairs of filtration tanks. In the filtration tank a perforated plastic plate was placed 20 cm above the bottom, and plastic pipes with small holes at every 30 cm were placed on the plastic plate. A layer about 60 cm thick of 1.5 cm diameter gravel was filled over the plastic plate. Two filtration tanks were used alternately, the unused one being washed at intervals by compressed air sent through the pipes.

In a later year Motokawa built a five ton tank system on nearly the same principle as its predecessor. The dimensions and capacity of this five ton tank are presented in Table V compared with those of the smaller tank. The table also shows the results of carp culture in these two types of recirculating systems.

The records of the carp cultivation in such water circulating systems are given here for only two cases, which may not be sufficient to appraise the true efficiency of the system. But they show the highest production of carp per unit of water utilized (see Table III) compared with all the systems of carp culture adopted in the country. This system may be recommended for other places where there is an acute shortage of water and the investment needed to build such a system can be expected to be realized from the fish produced. The operation of this system, similar to that of running of an aquarium requires rather specialized techniques.

3 CONTROL OF AYU (*PLECOGLOSSUS ALTIVELIS*) SPAWNING BY LIGHT

The ayu (*Plecoglossus altivelis*) is not strictly a warm-water fish but it is cultured in ponds in Japan during the summer months, and a new technique has recently been introduced to control its spawning by means of light.

The ayu is a smelt-like fish with a life span usually of one year. The 20 to 30 mm long young enter the rivers from the sea, growing to about 20 cm long by late summer, when they become a target for sport fishermen from July to September, before the downward migration begins. They spawn on the river bed gravels in the lower reaches of the rivers, after which most fish die. The hatched out fry are carried down to the sea where they overwinter.

Ayu culture starts every year with fry stocking, millions of fry being collected from beaches, estuaries and lakes. They are extensively fed on prepared feed, and harvested from June to August. Artificial fertilization and hatching of eggs is now practised experimentally, and work is in progress to put this on a commercial basis. One of the difficulties is to produce enough natural food (algae, rotifers, crustaceans, etc.) to feed the fry in pond water in October - November when the water is too cold to maintain these food organisms, for the artificial food used subsequently, cannot at present be used to replace the natural food for the postlarvae.

Experiments were therefore started using light to (i) speed up sexual maturation, to enable fry to be reared while natural food was still plentiful, and (ii) to delay spawning, and subsequently death, so that fish were available as out-of-season food for epicures.

These experiments were conducted at various fisheries stations and the ayu spawning time was both advanced and delayed by regulating the length of daylight hours or by exposure to artificial lighting (Nomura, 1964).

To effect earlier spawning the daylight hours were shortened to 19 hours by covering the pond by shading during May, then, daylight hours were returned to normal until mid-June, followed by sudden or gradual shortening by 5 to 6 hours from natural duration. The fish treated in this way began spawning activity from early to middle August, or 40 to 50 days after mid-June when shortening of light hours started. The sexual function varies with individuals, but its peak is observed 20 days after the beginning. Whatever the individual variations, the fishes treated thus spawned about two months earlier than those in natural rivers in the same region.

To retard the spawning of the ayu a simple procedure was followed: from July or early August to October, the daylight hours were extended to 14 to 18 hours by adopting electric lighting (for example, two 40-watt fluorescent lamps over the pond of 15 m^2). Those ayu which were exposed to extended light hours daily could survive until February to April the following year without reproductive activity. Some commercial fish farms in Tokushima and Shiga Prefectures shipped out the ayu treated in this way to market on New Year's day.

Even though it has been possible to regulate the spawning time of the fish, the control is not yet as precise as desired and further work including endocrinological studies are required to perfect the technique. The quality of eggs produced by the treated fish is poor as can be seen from data summarized below:

	Eggs shed by light treated ayu	Eggs stripped from river ayu
Diameter of egg (mm)	0.78 - 0.98	0.83 - 1.20
Hatching (percent)	65.17	74.39
Size of fry (mm)	3.8 - 6.3	6.0 - 7.3
Mortality immediately after hatching (percent)	47.0	0.1

4 HORMONE-INDUCED SPAWNING OF CHINESE CARPS, INCUBATION OF THEIR EGGS AND REARING OF FRY

In recent years several species of Chinese carps have been induced to spawn in ponds by injecting hormones into mature brood fish. The problems have been attacked nearly simultaneously in four places in Eastern Asia, Malaysia, Continental China, Taiwan and Japan. The development and details of the techniques used are not widely known, partly due to the difficulties of getting information published abroad, so the highlights of these new techniques are surveyed here.

4.1 Malaysia

In Malaysia where there is high demand for Chinese carp by local Chinese people, studies on the fishes have been carried out at the Tropical Fish Culture Research Institute, Malacca along with limnological investigations related to fish pond culture. The experiments on the spawning problems of those fishes in pond water have been attempted for several years; hormone injection studies were included recently but the results have not yet been fully reported.

Varying doses of follicle-stimulating hormone and luteinizing hormone have been given to both immature and mature grass-carp (Ctenopharyngodon idella), and the ovaries of the treated fish examined histologically. Follicle-stimulating preparations have a marked adverse effect on the metabolism of juvenile fish and appear to inhibit the development of eggs in adults. Luteinizing hormones on the other hand do not appear to affect immature fish in the same way and may accelerate the ovarian growth of adults. In some cases these hormones bring about the release of eggs from the ovary, but as an injection of saline on occasion has had the same effect, this is regarded as induced abortion.

In June a female grass carp weighing 6.5 kg was injected with 25 mg of fresh pituitary extract from Puntius gonionotus, and she produced about 5,000 eggs within 48 hours. The eggs, however, proved sterile although a male fish was present. A second smaller fish of 5.7 kg was also tried, but did not spawn although she contained ripe eggs. Tests made in August, November and December were unsuccessful and confirmed earlier findings that the gonads of grass carp regress during the months corresponding to autumn and winter in the north temperate zone. In this regressed condition they do not respond to the injection of pituitary extract.

At Malacca, Kurth (Prowse, in litt.) found it easy to make the fish shed eggs, but the eggs never went beyond the stage where the nucleus reached the micropyle, and they broke down before the micropyle opened. Injections of whole pituitary extracts seemed to accelerate the breakdown.

The ovaries rarely developed to more than 10 percent of the total weight of the fish. But in a flow experiment carried out in 1961 all the fish bulged with eggs and the cloaca was swollen in the typical fashion of a ripe fish. The ovaries were certainly more than 20 percent of body weight. Kurth later found no increase in size of ovary with flow treatment, but in this case the flow was continuous from the beginning whereas in the 1961 experiment the flow was gradually increased from a slow flow of one hour per day until in July to August it was a fast flow for 24 hours a day. This would suggest that graded flow to simulate natural conditions might be a factor in the development of the ovary (Prowse, in litt.).

4.2 Mainland China

4.2.1 History of artificial reproduction

In Mainland China, where three million tons of fresh-water fish are said to be produced annually, Chinese carps have been studied very extensively in recent years. The old tradition of collecting fry of these fishes from river waters has now changed into producing them artificially.

The induced spawning is a recent development. According to Wu and Chung (1964), the suggestion of making an artificial breeding ground, simulating the environment of the natural one, was first made in 1952 and between 1951 and 1953 fishermen of Kweipin, using artificial fertilization of mature silver (Hypophthalmichthys molitrix) and grass carps obtained millions of fry. In 1954 the Academia Sinica biologists tried pituitary treatment on mud carp (Cirrhina molitorella) and bighead (Aristichthys nobilis), which had reached maturity in the rivers (using common carp pituitaries), inducing them to spawn earlier than normal. In 1955 the Southsea Fisheries Institute reared silver carp and bighead to maturity in a pond in Canton and obtained fry by pituitary treatment. In the autumn scientists of these two institutions induced two species to spawn using chorionic gonadotrophin from human pregnancy urine. Grass carp were produced by artificial propagation in several institutions in 1960, and in 1963 mud carp fry were obtained.

The work was experimental until 1961, but nation-wide production of fry by artificial means reached 1200 millions in 1962. In Chekiang and Kwantung fry production already fulfils the requirements for pond fish culture in these two provinces.

4.2.2 Treatment of brood fish

The brood fish to be used in artificial propagation are stocked in brood fish rearing ponds, 0.2 to 0.4 ha and 1.5 to 2.0 m deep, in which the treatment varies with number of fish stocked as shown in Table VI.

Table VI

The numbers of fish stocked per ha and management of three types of brood fish ponds in Mainland China[1]

	Silver carp pond	Bighead carp pond	Grass carp pond
Silver carp	200 - 250	10 - 20	100 - 150
Bighead carp	20 - 30	100 - 150	10 - 15
Grass carp	100 - 150	100 - 150	150 - 200
Management	Fertilization needed	Fertilization needed	Grass fodder and commercial feed given
Water	Refilled once or twice / month	No refilling of water	Refilled once or twice / month

[1] Note: Size of fish stocked: 2.5 to 4.0 kg silver carp, 5 to 10 kg bighead carp, 4 to 10 kg grass carp.

The brood fishes should have reached the age of sexual maturity. The age at which females mature in different parts of Mainland China is as follows:

	Silver carp		Bighead		Grass carp	
	Years	Weight (kg)	Years	Weight (kg)	Years	Weight (kg)
South	2 - 3	2 - 5	3 - 4	5 - 10	4 - 5	6 - 8
Central	4 - 5	2 - 5	4 - 5	5 - 10	4 - 5	6 - 8
North	5 - 6	2 - 5	6 - 7	5 - 10		6 - 8

The male fish usually ripen one year earlier than the females throughout the country. The number of eggs carried by a mature female is said to be 100,000 to each kg of body weight in Kwantung Province. The recommended sex ratio for natural fertilization is one female to two males, but for the purpose of artificial insemination equal numbers of both sexes are stocked in the ponds.

4.2.3 Inducement of gonad maturation

The hormone injection to induce maturation of the gonads is made before the fish are transferred to the spawning pond. This pond is about 100 to 140 m^2, with water between 1.5 and 2 m deep, with an inlet and outlet system. The shape (whether circular or rectangular) is not standardized, but the bottom should be smooth and level and kept clean. Suitable conditions in the pond appeared to be conducive to spawning activity, important in bringing the fish into a spawning state, and increasing the number of eggs to be laid and the percentage fertilized (especially in the grass carp). Running water with a current velocity of 0.2 to 0.4 m/sec proves effective in stimulating the fish to spawn.

There are two common egg-maturation inducing agents in current use in Continental China, pituitary of common carp and chorionic gonadotrophin; the pituitaries of other cyprinids like Carassius auratus, Squaliobarbus curriculus and the four species of Chinese carps themselves are also effective. Mammalian anterior lobe preparations, frog pituitary and the pituitaries of Tilapia and Coilia gave negative results. Fish pituitaries may be used fresh or may be dehydrated and preserved in acetone or absolute alcohol for later usage. The two common agents named above are generally effective for all the four species, although chorionic gonadotrophin does not seem to work on grass carp. Dosages suggested are 3 to 3.5 glands of common carp (about 0.5 kg in weight) to one kg of recipient fish, or 2 to 3 mg dry gland per kg of fish. The appropriate dosage for chorionic gonadotrophin is 700 - 1,000 IU per kg. To 10 to 15 pituitary glands 1.5 - 2.0 ml normal saline is added to make a suspension. When chorionic gonadotrophin is employed, the calculated amount of the hormone is dissolved in 1.5 - 2.0 ml normal saline injection.

Intraperitoneal and intramuscular injection are both effective, but the former is more commonly used, the injection being made at the base of the pectoral or pelvic fin. The dose is usually delivered in a single treatment, but may also be divided into two injections. In the latter case the first injection should contain one quarter to one third of the total dose, and the second the rest.

The water temperature for spawning in these Chinese carps ranges from 20° to 30°C (preferably 23° to 29°C), and any deviation above or below this range tends to inhibit the spawning activity to a varying degree. The presence of male fish in the pond may serve as a stimulus for sexual activity. It is generally observed that the brood fish after being injected with hormones and transferred to the spawning pond become sexually active in due time, usually 10 - 14 hours after the single injection or six to eight hours after the second injection, although variations occur according to water temperature and other factors.

When the fish are ready to spawn, ripples begin to appear intermittently on the water surface as a result of the spawners chasing around. About 40 to 80 minutes later, the male and female ascend close to the water surface, chasing each other and shedding eggs and sperm. For artificial insemination the brood fish are promptly removed from the water at this stage.

4.2.4 Fertilization

Stripping of milt and eggs is performed immediately after the spawning fish are taken out of the water, and insemination is carried out by the dry method. Spermatozoa in undiluted milt can live for a relatively long period; in normal saline they may survive for 20 to 35 minutes; in fresh water, only about one minute. The milt is dropped into the pan in which the eggs have been placed (if the milt is scarce, it may be mixed with a small amount of normal saline). The eggs are stirred gently with a feather, or by rotating the pan for about one minute, then fresh water is added. After rinsing once or twice, the eggs are transferred to the hatching apparatus.

As an alternative, one may let the fish finish spawning right in the spawning pond. The process of egg-laying usually lasts 30 to 90 minutes. One or two hours after egg-laying, when the eggs have absorbed water and their membrane has hardened the eggs can be collected at the entrance to the drainage ditch by means of a floating net-box. This "natural fertilization" usually gives more satisfactory results, in as much as it is free from drawbacks which sometimes accompany the artificial insemination, like inferior quality of eggs obtained due to untimely stripping.

4.2.5 Hatching

The fertilized eggs may be hatched either outdoors or indoors. Outdoors, the hatching apparatus containing the eggs is placed in a creek or rivulet with a sluggish flow, or in standing water with plenty of good quality water.

The hatching apparatus is a topless rectangular box of approximately 80 X 50 X 35 cm, of nylon sievecloth or hemp, with meshes of 0.8 - 1 mm, stretched upon a rectangular wooden frame. In recent years, an octagonal variety has been used with greater success. The density of eggs is generally kept at four or five per square cm of bottom. In the course of hatching, noxious organisms such as the fry of other fishes, shrimps, aquatic insects and water fleas have to be excluded. In standing water, the eggs should be lightly stirred once every 20 to 30 minutes. After the fry hatch out, the egg membranes should be removed from the apparatus. Recently, for mass production of fry, a circular "race course" supplied with running water has been developed for hatching the eggs, and the results are highly encouraging. Indoors, hatching bottles and troughs are at present used. Since the water temperature, dissolved oxygen content and light, as well as natural enemies can be controlled, indoor hatching is usually more satisfactory.

4.3 Taiwan

4.3.1 Experimental work

In Taiwan where also there is high demand for Chinese carps for pond culture, fingerlings had to be imported yearly from Mainland China through Hong Kong; recently a few also came from Japan. These introduced fish never matured, neither in ponds nor natural bodies of water, making it necessary to import fingerlings every year. Chinese carp were not known to spawn in Taiwanese waters until 1959, when grass carp and silver carp were discovered spawning naturally in mid-Taiwan. In 1963 pituitary injections were used to induce spawning in these two species during their spawning season, and in 1964 about five million Chinese carp fingerlings were produced artificially by local hatcheries (Tang, MS).

In Taiwan spawning has also been induced in the mud carp Cirrhina molitorella by injection. The technique is as for silver, bighead and grass carps, but this species is also responsive to heteroplastic injections, positive results having been obtained with injections of skipjack tuna (Katsuwonus pelamis) pituitaries, and 500 rabbit units of cattle anterior pituitary combined with fresh toad pituitaries. On cool, rainy days carp stimulated by exogenous gonadotrophin spawned in the holding ponds; Lin reported high fertility among naturally fertilized eggs from the hormone-treated fish. However, Tang et al. (1963) reported that of 33 spawners treated only 22 reacted to it.

Taiwanese workers found when injecting Chinese carps that one or two injections of one or one and half pituitaries from donor carps of comparable size were the average dose for the female; half to one pituitary sufficed for the male. An overdose of hormones was found to cause high mortality of eggs during hatching.

Difficulties in techniques of hatching, including high water temperatures which reduced the hatching time, rapid fluctuations in water temperature, and protozoan parasites were observed to cause the death of appreciable numbers of eggs and hatchlings. The majority of the eggs from the hormone-spawned fish were fertilized and hatched normally. The young fish obtained by this method were also observed to grow normally in comparison with those from natural spawning.

4.3.2 Feeding of fry

Tang et al. (1964) suggested that artificial feeding of the Chinese carp hatchlings should be started 48 hours after they emerge from the egg capsules (temperature of the nurseries 27° to 31°C). This is because the hatchlings generally begin to take protozoa and micro-algae as food from this time. Experiments on artificial feeding with wheat flour, peanut cake meal, rice bran, soybean milk and yolk of boiled duck eggs showed that the last two items gave better results than the others. Soybean milk combined with duck's yolk resulted in better results, in growth as well as survival than any other materials given alone. Such organisms as ciliates and daphnia appear to be important food items in natural water, but there is no evidence to show the superiority of these organisms over the artificial food for the growth and survival of Chinese carps at their larval stage.

Fry can be reared in glass tanks with satisfactory growth rates, but thereafter the fish grew better when transferred to earth ponds. Microscopic crustaceans were satisfactory food items until one month after hatching, but after that period they fed better on duck-weed. The mortality of fry smaller than 10 mm was high, but the fish one month old, 33 mm long, were stronger and mortality was lower.

4.4 Japan

4.4.1 History of experimental work

Chinese carp were introduced in Japan nearly three decades ago, but were first observed to spawn in late 1940 in the Tone River system. These fishes have been studied at a number of fisheries stations (Kuronuma, 1954) but the most extensive experiments, including hormone-induced spawning, were carried out at the Saitama Prefecture Fisheries Experiment Station located near the site where these fishes had spawned in the Tone-River. Most of the original data given here come from this station.

Since 1955 several institutions have collected Chinese carp spawn (mainly grass and silver carps) from the Tone-River during the spawning season (June to August), from which fingerlings were reared by September or October in Station ponds. In recent years nearly 100 million eggs have been collected, producing some 20 million fingerlings, some of which were exported. In addition to the station where the work started ten years ago, some ten commercial fish hatcheries now produce fry.

The stimulation of spawning by hormone injections first attempted in 1960 was finally successful in 1965; in the intervening years eggs failed to hatch or grew into deformed fry.

4.4.2 Recent experiments

An outline of the procedure followed during the successful experiments carried out between June and August 1965 by the Saitama Fisheries Station in collaboration with the Freshwater Fisheries Research Laboratory is given here (Saitama, 1965; Kafuku, personal communication), though analyses of the experimental data are not yet complete.

The brood fish were caught by drifting gill nets in the Tone River on the spawning grounds of the two species of Chinese carps, which extend 20 km along the river, 150 km from the estuary. The fish were anaesthetized by MS-222 and brought to the station ponds in a live-box with a small amount of water . Transportation from site to station took about 30 minutes by truck. In addition to river-caught fish, some pond-reared grass and silver carp were also tested for hormone-induced spawning, but they did not respond well compared to those derived from the river.

Upon arriving at the station pond the fish were injected. The hormones used were pituitary glands of grass and silver carps, synahorin (20 to 50 rabbit units) and gonadoplex-Leo (1,000 or 3,000 IU). The pituitary gland was used either fresh or stored in alcohol. The dosage was determined by the sexual maturation of fish (external observation), and the injection was repeated two to five times, most often two or three, again depending on the sexual condition of the fish. Injections were generally made into the body cavity behind the pelvic fin. The fish under treatment were placed in river-water fed ponds measuring 9 X 2.7 X 1.2 m or 14.4 X 7.2 X 1.2 m.

Fully ripe male fish which were caught without difficulty nearly all the time during the spawning season, were placed in the pond, or kept in the pond ready for fertilization. After witnessing the "chasing" behaviour of the spawning fish or egg-shedding by the female, the eggs were either collected from the pond water or trapped at the outlet gate, or alternatively the female was removed and stripped (the ripe fish discharging eggs very easily) or the eggs were dissected out. Eggs were fertilized by the dry method.

In the 1965 experiment 16 grass and silver carps all from Tone River, were used between 22 June and 16 July. They were treated differently depending on their ripeness and nine produced eggs (two grass carp and seven silver carp). The eggs were discharged freely in fully ripe fish, but some females had evidently not reached full maturity. These required repeated strippings (up to five times) and on incubating the eggs only the batches from the first and second strippings (20 percent) hatched out normally 46 to 52 hours after fertilization (at 22°C); the rest started to develop and then died. The grass carp treated ranged from 77.5 - 102.0 cm long, 7.0 - 14.9 kg weight, the ovaries weighed from 1.98 - 2.90 kg, forming 19 - 28 percent of the body weight and produced from 1,140,000 to 1,670,000 eggs. The silver carp treated were fish between 88.0 - 98.5 cm long, 9.5 - 11.0 kg weight, in which ovaries weighed 2.2 - 2.7 kg, forming 20-25 percent of the body weight, and produced from 1,098,000 to 1,392,000 eggs.

4.4.3 Hatching of the eggs

The Saitama Fisheries Experiment Station designed an incubation net-frame of high efficiency for the hatching of Chinese carps eggs in 1958, which has been used ever since. The apparatus placed in a hatching box fed by running water gave a 90 percent hatching rate for the river-collected eggs of the two species. The net-frame, a rectangular box shaped and narrowed at the bottom, measures 39 X 33 cm at the top, 20 X 20 cm at the bottom and is 53 cm deep, and the net (nylon sievecloth of three mm) is supported by wooden frames at the upper rim of the frame on four sides, and the net is spread for 29 cm below the wooden piece; the bottom of the net is trimmed into a funnel 5 cm deep with opening 6 cm in diameter. The funnel part of the net is reinforced by wire instead of wooden frame.

The hatching box, also of wood, measures 176 X 42 cm wide and 60 cm deep, and receives three net-frames. The box is separated into three compartments each with raised (3 cm) floor above the bottom of the box. Each compartment has a round hole on the floor into which a short plastic tube is inserted, which stands directing to the funnel opening of the net-frame when the latter is placed in the box. The separation inside the box into three compartments is made so as to lead the water entering from one side of the box to bottom space underneath the first compartment, the water overflowing from here is led to the bottom of the second compartment, and in the same way, water is led to the third one. In the hatching box constructed in this way, the water always flows upward into the compartment (where a net-frame is placed) through the plastic pipe planted on the floor, so that "semi-floating" eggs are kept in constant circulation within the net-frame. The water running through the three compartments flows out of the box through a notch cut on the upper edge of the box side. The amount of water fed into the box is carefully regulated so as to give constant and well balanced movement to the eggs; experience showed 20 litres per minute to be appropriate.

The net-frame described above can accommodate 5 to 10 litres of eggs (about 50 to 100 thousand eggs), and the box carrying three net-frames accommodates 15 to 30 litres (150 to 300 thousand eggs). The hatchlings float up and are carried by the water current through the net meshes, and are finally brought down to the outlet notch mentioned above. The fry coming out of the box with water are collected in the fry-rearing-tray which is placed at the side of the box. The rate of hatching is always as high as 90 percent.

4.4.4 Rearing of fry to fingerling size

The fry-rearing tray is a wooden frame measuring 100 X 60 X 18 cm with nylon sievecloth forming the bottom floor. The tray is floated in a concrete tank with a moderate flow of water. The fry just hatched out are reared for about one week until they float up to the surface of the water and can swim in the flowing water. Daphnia (smaller than 0.5 mm) are fed three days after the fry hatch out, but feeding has been stopped in recent years. One tray can rear the fry received from one hatching box. The use of the tray has been often omitted, and the fry transferred directly to nursery pond or net-cage described below.

The growing of fry to fingerlings is carried out in small concrete or earth ponds, which are also used for common carp at the same stage. Several years ago the station adopted the net-cage system of rearing fry in addition to the nursery pond just mentioned.

The net-cage is square and measures (in one type) 1.8 X 1.8 X 0.9 m, and made of nylon sievecloth with 30 to 40 meshes. Bamboo sticks are used to keep the shape. The cage is placed in pond water, with the water 50 to 70 cm deep in the net, fixed tightly to wooden stakes into the pond bottom. The net-cage of this size can hold 50 to 200 thousand fry 10 mm long, or 15,000 to 62,000, i.e. per m^2. The holding capacity of the net-cage is amazing compared with the ordinary stocking rate of 1,400 to 1,800 in the same area of nursery pond. Experience shows that it is desirable to pour a small amount of water over the cage from a hose. The number of fish stocked in the net-cage affects the rate of growth, as an experiment conducted in 1963 clearly showed. Four lots of fry were reared for 22 days from 8 July in four net-cages of the same size under similar conditions, and the results are tabulated below. This shows that stocking with 70,000 fry gave the best results both in weight increase and survival. However, it must be remembered that the fingerlings reared in the net-cage are meant to be used for stocking, so the larger size of fish is not necessarily appreciated.

Lot	No. of fish stocked (in thousands)	Harvest		
		No. of fish	Total weight (kg)	Survival (percent)
1	150	125,000	16	83.3
2	100	72,500	17.5	72.5
3	70	61,900	21.8	88.4
4	50	43,900	18.5	87.8

The feeding practice shows slight changes from year to year, but a method adopted in 1962 at the station gives a general idea: the feeding starts when the fish become accustomed to the environment, giving first a mixture of yolk of chicken egg (52 percent), animal liver (14 percent), soybean cake (18 percent), fermented soybean (9 percent), and flour (5 percent), the mixture being sprayed over the water surface. When the fish grow some two cm long (17 days after the stocking) a new diet is given consisting of flour (38 percent), mixed fish meal (38 percent), rice bran (16 percent) and silkworm pupae meal (8 percent) in addition to the former, but the amount of the latter is increased gradually until finally the former is entirely replaced by the latter.

The rate of growth in the net-cage was from 8 mm to 26 mm during 26 days in June and July 1962 at a temperature of 21° to 31.5°C, but the fish grew to the same size within 15 days in 1961. The lower temperature of water in 1962 than in 1961 (28° to 33°C) was mainly responsible for the slow growth.

4.5 General discussion

The accumulation of empirical data on hormone spawning is very useful, but an analytical approach in planning and execution of experiments is needed to achieve greater understanding. Coordination between endocrinologists and fishery biologists is needed.

Fish pituitaries extracted from the same or related cyprinids gave best results particularly when chorionic gonadotrophin was added.

It is clear that the fish to be treated must be ripe enough to be within one step of reaching the last stage of sexual maturity at the time of hormone treatment; an immature fish will not respond to treatment. The physiological effects of the hormones need study, and whether the stimulus accelerating the ripening of the gonads also affects the discharge of the sexual products. At the Malacca Fish Culture Institute column electrophoresis of fish pituitaries has been started, to analyze the changes which take place in fish which do not spawn, compared with those that spawn freely (Prowse, *in litt.*).

The Malacca work has also emphasized that water flow will stimulate sex behaviour along with sexual motivation accumulated internally, and the movement of water in the spawning pond is definitely needed for this purpose. In nature Chinese carp spawn in flowing water. The temperature of the pond water is also of vital importance in regulating the sexual cycle of the fishes.

The hatching of Chinese carp eggs also requires flowing water, though the physiological reason for this is not yet known.

The net-cage container developed in Japan for rearing fry and fingerlings is highly recommended. The principle underlying this is by no means new, but it can be extended to various species of warm-water fish reared in standing water. Whether or not the larval fish should be fed on daphnia at first needs investigating, but egg yolk has been found to be a very satisfactory ingredient in the initial food for rearing Chinese carp fry.

5 FISH VARIETIES AND HYBRIDS

5.1 Varieties of common carp

Despite the multifarious techniques of fish culture developed in various parts of Far East Asia, each well adapted to the natural conditions and socio-economic set-up of that region, not much attention has been paid to seek new types of fish suitable for pond culture. A number of goldfish varieties have been created artificially in China and Japan, and fancy or coloured varieties of the common carp, but these fish are decorative fishes for garden ponds or aquaria, or just curiosities. These have not contributed to nutritional resources, although the hatcheries of these fishes have made an appreciable amount of profit, especially in Japan.

Other varieties of common carp, if they can be called new fishes, have been investigated to some extent. For instance, mirror and leather carp were introduced to Japan from Germany in early 1900, but they have not become popular as the people, who had been accustomed to ordinary scale carp were rather prejudiced against these new varieties. Under such circumstances fish breeders and fishery workers have not paid much attention to them, nor have they been studied carefully to find out whether they may have desirable characteristics in comparison with native scale carp. The fatness of some varieties of scaleless carp is remarkable (Swingle, 1965).

5.2 Hybridization of cyprinid fishes

As pointed out before (Kuronuma, 1962) the carp goldfish hybrid came to the attention of a number of anatomists and geneticists in Japan, and its biological characters have been made clear to a certain extent. The ease of crossing carp and goldfish is believed to have lured many hatchery men and biologists to breed the hybrid, but the significance of the hybrid or their back-cross off-spring as pond fish has not been critically studied. Whether they show better growth than parent species, or have any other special value for cultivation has not been answered in this part of Asia.

The crossing of Chinese carps with Indian carps has been attempted along with hormone-induced spawning of these fishes, but none of them showed satisfactory results (Alikunhi et al., 1963). In Taiwan successful hybridization occurred between Chinese carps and common carp and goldfish (Tang, MS). Male H. molitrix with female A. nobilis and its reciprocal cross produced thousands of off-spring which grew very well. Also, Liu (1964) reported the hybrid from crossing C. molitorella and C. carpio to have grown to an average size of 1.35 kg during a period of one year in an ordinary fish pond. It is hoped that the work will proceed further and produce fast-growing or other favourable strains to contribute to fish culture.

5.3 Tilapia hybrid

Interspecific hybridization of Tilapia species has been made by several workers in Malaysia, Israel, Africa and elsewhere (Hickling, 1962). With the exception of the crossing between T. mossambica and T. hornorum which produces mono-sexual offspring the tilapia hybrids so far produced experimentally have not contributed much to fish culture.

The all-male hybrid Tilapia mossambica produced at Malacca grow to a weight of more than 450 g in six months, growing twice as fast as either parent stock. The production of these all-male hybrids is as easy as breeding pure-bred young, in fact the number of young produced may be greater, and their production for stocking ponds, where they grow well as they cannot breed, has become a routine at the Malacca Tropical Fish Culture Research Institute (Malacca 1964).

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NEW SYSTEMS AND NEW FISHES FOR CULTURE IN THE UNITED STATES

by

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Abstract

Commercial pond culture for production of food fish is a recent development in the United States. Four new systems of commercial pond culture are described. Channel catfish are the most desirable species for fresh-water pond culture because of their efficient conversion, high production and acceptance by the consumer at above average prices. A net production of 2,423 kg per ha is reported for 252 days.

Brackish-water pond culture is undeveloped; however, preliminary experiments on native species indicate that it is feasible. Shrimp production of 1,387 kg per ha in 4.5 months is reported.

NOUVEAUX SYSTEMES D'ELEVAGE ET NOUVEAUX POISSONS AUX ETATS-UNIS

Résumé

L'élevage commercial en étang de poissons destinés à l'alimentation humaine se pratique depuis peu aux Etats-Unis. La communication décrit quatre nouveaux systèmes de pisciculture commerciale. Les "channel catfish" (Ictalurus punctatus) sont particulièrement recommandés pour l'élevage en étang d'eau douce à cause de leur taux de conversion élevé, de leur forte production et parce qu'ils se vendent à un prix supérieur à la moyenne. Une production nette de 2 423 kg par ha est signalée pour une période de 252 jours.

La pisciculture en étang d'eau saumâtre ne se pratique guère; toutefois, des expériences préliminaires avec certaines espèces indigènes indiquent que ce type d'exploitation pourrait être rentable. Enfin, une production de crevettes de 1 387 kg par ha en 4/5 mois est signalée.

NUEVOS SISTEMAS Y NUEVOS PECES PARA SU CULTIVO EN LOS ESTADOS UNIDOS

Extracto

La piscicultura comercial en estanques para la producción de peces comestibles constituye una novedad reciente en los Estados Unidos. Se describen cuatro nuevos sistemas de piscicultura comercial. Para la piscicultura en aguas dulces, la especie más comveniente es el bagre de canal a causa de su eficaz índice de conversión, elevada producción y aceptación por el consumidor a precios bastantes elevados. Se menciona una producción neta de 2,423 kilogramos por hectárea en 252 días.

No está desarrollada la piscicultura en aguas salobres; sin embargo, los experimentos preliminares en especies indígenas indican que aquélla es factible. Se dan noticias de una producción de camarones de 1,387 kilogramos por hectárea en 4/5 meses.

1 INTRODUCTION

Commercial production of fish in ponds for food appears to be a feasible and desirable use for many areas in the Southeastern and South-Central United States. Davison (1954) states that all rice-land soil is suitable for fish production and has an available water supply and there are approximately 800,000 ha of rice-land in the United States. Even though land and water were available, development of an interest in the commercial production of warm-water food fish is a recent event which has taken place in the last 20 years.

The initial development of fish farming was closely related to the expansion of rice production in the Mississippi Delta. Farmers found that weeds could be eliminated from rice fields most easily by flooding to a depth of 45 cm or more for two years. (Johnson, 1959). The concept of stocking flooded fields with fish is so obvious it is hard to conceive that the first rice grower to fallow land in this manner did not also produce a crop of fish.

According to Hulsey (1967), some of the factors which eventually contributed to the recent intense interest and development of food fish farming in Arkansas are: (i) surplus crop lands idled due to controls on the production of rice and cotton; (ii) large acreages of submarginal land that could be used for reservoirs; (iii) construction of a large number of surface water storage reservoirs for crop irrigation and flooding green timber to provide duck shooting areas; (iv) the high value for marketable fresh-water fishes, and (v) the need for a better crop rotation system in rice culture.

Hogan (1953) reported on the feasibility of commercial fish farming on rice-lands, and Hogan and Stevenson (1954) in surveys of commercial fish production in Arkansas reported propagation of several species. In 1952, 110 ha and in 1953, 1030 ha were in food fish production. These impoundments consisted of irrigation reservoirs, flooded areas for clearing timber, and rice fields on which the outside levees had been raised.

The principal fish produced in rice fields was the bigmouth buffalo, Ictiobus cyrpinellus (Valenciennes). Two others were produced to a lesser extent: the smallmouth buffalo, Ictiobus bubalus (Rafinesque) and the black buffalo, Ictiobus niger (Rafinesque). The smallmouth buffalo has a smaller head and yields a higher percentage of dressed weight, consequently it is the best market fish of the three. The bigmouth buffalo was preferred by the producers because it was hardier and higher production could be obtained. Some carp, Cyprinus carpio Linnaeus, were produced, but they were not of importance since they had only approximately one-third of the market value of buffalo.

In 1948, Swingle (1954) initiated experiments on the production of various species of fish on a commercial basis. From these experiments he concluded that the bigmouth buffalo and smallmouth buffalo appeared to be the most promising. In 1948, the Fish and Wildlife Service (unpublished data) experimented with the production of striped mullet, Mugil cephalus Linnaeus, in several locations. These experiments were discontinued when the production with fertilization did not exceed 100 kg per ha per year.

At the present time there are approximately 28,300 ha in commercial warm-water food fish production. Several different cultural systems have been developed or are under development. These fish cultural systems are discussed below.

2 CULTURE OF BUFFALO FISHES

There are three species of buffalo fishes: bigmouth buffalo, smallmouth buffalo, and black buffalo. The bigmouth buffalo received initial consideration as a commercial pondfish because of its availability, it was already a commercial food fish that grew well in ponds. Bigmouth buffalo are found in the Central United States from the Red River of the North through the Mississippi Valley to Texas, Louisiana, and Alabama. Buffalo fishes are river species which normally spawn on submerged vegetation in backwaters when rivers overflow in the spring of the year. Canfield (1922) reported that these fishes could be spawned successfully by placing them in partially filled ponds and rapidly filling the pond when the water temperature reached 15.6-16.7°C. Walter and Frank (1952) reported using the same procedure in producing smallmouth buffalo. They also produced bigmouth and smallmouth buffalo fry by stripping and hatching the eggs in jars. Swingle (1954; 1956) found that the bigmouth and smallmouth buffalo produce a repressive factor that prevents or retards reproduction. This factor, if taken into consideration, permits control over spawning.

Brady and Hulsey (1959) described a method for propagating and rearing bigmouth buffalo. Swingle (1954; 1957a) gave procedures for commercial production.

To produce bigmouth buffalo, select the fastest growing fish in the 1.36 to 3.63 kg range for brood stock. Stock brood fish in wintering ponds at rates 450 to 675 kg per ha for fertilized ponds and 1,100 to 2,250 kg per ha if the fish are fed. Feed a prepared fish feed 1/ at the rate of 1 percent of the body weight per day when water temperatures are over 13°C. In the spring when water temperatures rise to between 18 and 21°C, fill the spawning pond with fresh water from a source which does not contain buffalo fishes. Stock brood fish at the rate of 20 to 25 pairs per ha. Spawning usually occurs within 24 hours and young are visible in seven days. The number of young produced per ha ranges from 50,000 to 250,000.

When the young buffalo reach 2.5 cm, they can be stocked in nursery ponds at rates up to 25,000 per ha. If nursery ponds are fertilized, 10 to 12.5 cm fingerlings will be produced (450 to 550 kg per ha) six months after stocking.

Fingerlings may be stocked in growing ponds in the fall, winter or early spring. The rate of stocking varies depending upon the size of fish desired for market, the productivity of the ponds, and the length of the growing period. After stocking buffalo fingerlings, growing ponds should be stocked with about 125 large largemouth bass [*Micropterus salmoides* (Lacépède)] fingerlings per ha to control wild fish.

Mortality rates vary greatly in handling fry for stocking nursery ponds and mortalities up to 50 percent have been reported. Mortalities in growing ponds do not exceed 5 percent per year. To reduce mortalities, brood stock and fingerlings should be treated for control of external parasites and diseases each time they are handled.

Buffalo fishes will grow from 1.3 to 2.8 kg per year in ponds if stocked at low rates. In Arkansas, stocking at the rate of 1,250 per ha in unfertilized ponds produced 567 kg per ha. Twice this production was obtained when the growing ponds were fertilized or when buffalo followed rice in rotation. In ponds in Alabama, stocking at the rate of 593 per ha in fertilized ponds produced fish averaging 0.58 kg in six months, 0.91 kg in one year, and 1.09 kg in 18 months. Stocked at the rate of 297 per ha, buffalo fish averaging 0.64 kg were produced in six months and 1.63 kg in 18 months (Table I). Feeding with soybean meal gave higher production than fertilization only; however, the cost exceeded the value of the product.

Buffalo fishes contain many small bones which consumers find objectionable, and so the larger fish are preferred. In certain areas small buffalo can be marketed; however, a 2.7 kg buffalo is considered the minimum marketable size for most inland markets. Buffalo weighing 4.5 kg and over bring a premium price.

1/ Feed used consisted of 35 percent soybean oilmeal, 35 percent peanut oilmeal, 15 percent fish meal and 15 percent distillers dried solubles.

Table I

Production of bigmouth buffalo fish (Ictiobus cyprinellus) in Alabama at different stocking rates, treatments and growing periods

From Swingle (1954; 1957a)

Rate of stocking No. per ha	Av. initial wt (g)	Treatment and growing period	Production/hectare	
			No.	weight (kg)
		One year		
4,670*		Fertilization and Feeding**	4,596	927
4,942*		Fertilization and Feeding	4,695	1,007
7,413*		Fertilization and Feeding	7,067	1,257
1,067*		Fertilization only	1,067	709
1,067*		Fertilization only	1,058	686
1,067*		Fertilization only	1,067	575
		Six months (May to October)		
297	23	Fertilization only	2,420	152
593	23	Fertilization only	455	274
		18 months (May to October)		
297	23	Fertilization only	297	475
593	23	Fertilization only	563	606

Buffalo fishes are sometimes raised in rotation with rice. The growing pond may be under fish production two years and under rice production one or two years. Some ponds are rotated on a yearly basis from rice to fish to soybean and then the rotation is repeated. Stocked at rates of 125 to 250 per ha, buffalo fishes will reach marketable size in two years. Production of buffalo fishes at this rate of stocking is 300 to 400 kg per ha per year. When stocked at higher rates, better production is obtained; however, at the end of two years these buffalo fish are too small to market. They must then be transferred to other ponds.

Guidice (1964) states that one means of overcoming this problem is to improve the species through cross-breeding. All possible mating combinations were tried with the three species of buffalo fishes. Black[1/] x bigmouth, black x smallmouth, and smallmouth x bigmouth crosses were successfully produced by stripping and hatching in jars. The black x bigmouth was the only cross successfully produced in ponds.

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* Mixture of bigmouth and smallmouth buffalo

** Soybean meal fed

[1/] Females listed first in all crosses

All three crosses showed accelerated growth rates; however, the increase was the most pronounced in the black x bigmouth. After one year in a growing pond, this cross was 33 percent heavier than the parent species. Should these growth rates continue during the second year, larger fish could be produced two years after stocking in growing ponds.

Although buffalo fishes were the species that led to the development of commercial food-fish culture, they have been largely replaced by channel catfish.

3 CULTURE OF CATFISHES

The low price of buffalo fishes and the difficulty in producing a marketable-sized product resulted in the expansion of research on catfishes. The southern brown bullhead (speckled bullhead, red cat), Ictalurus nebulosus marmoratus (Holbrook), received early attention because it reproduced readily in ponds, and fingerlings for stocking were easily obtained.

Swingle (1954) reported that in one-year experiments with southern brown bullheads, 214 to 319 kg per ha could be produced with fertilization and 1,652 and 1,932 kg per ha with fertilization and supplemental feeding using soybean meal and cake. The fact that they reproduced readily created a problem. Feeding these fish in growing ponds during the spring and summer resulted in heavy reproduction. Small fish (7.5 to 10 cm) made up 59 to 70 percent of the total weight of fish produced.

This problem was avoided by stocking southern brown bullhead fry or fingerlings in growing ponds in the spring. These growing ponds were fertilized in the spring and summer and the fish fed during the fall and early spring. Prior to spawning time the pond was drained and the fish harvested. While successful, this technique limited the usefulness of this fish as a commercial species.

In later studies, Swingle (1957b) found a repressive factor developed and reproduction did not occur with stocking rates of 7,400 to 14,800 per ha, provided the size of the fish stocked was from 2.5 to 10 cm. Using the small fingerlings and higher rates of stocking it became possible to stock at any time and operate commercial growing ponds throughout the summer without the stock being increased by spawning.

The most economical production was obtained by stocking 7,413 fingerlings per ha in June. The pond was fertilized and beginning in August the fish were fed as long as the water temperature was above 60°. At the end of 13 months, 1,012 kg of marketable fish were obtained.

The generally accepted minimum marketable size for catfish is 0.34 to 0.45 kg live weight. Smaller bullheads can be sold to speciality restaurants; however, the increased cost of production and marketing exceeds the return.

Channel catfish, Ictalurus punctatus (Rafinesque), when compared to the southern brown bullhead as a commercial pond species had many desirable attributes. Channel catfish were less susceptible to disease, did not ordinarily reproduce in ponds, grew to a larger size, had a more efficient food conversion and higher production per ha. They also were an important commercial and sport fish in many streams, lakes, and impoundments. Channel catfish were originally present in the Great Lakes and Mississippi Valley of the United States. As the result of introduction into drainages on both the Atlantic and Pacific Coast, they have now a wide distribution in the United States.

Channel catfish was considered to be an excellent food fish and with a natural supply inadequate to meet the demand. Initial development of commercial culture was limited by the availability of young.

Production of channel catfish in hatcheries was not new, having been described by Morris (1939); however, it was so erratic that it was necessary to develop and refine hatchery techniques. Nelson (1957) and Crawford (1958) both describe similar methods to produce channel catfish in ponds. Wire or concrete block spawning pens 1.5 metres wide and 3.0 metres long were constructed around the edge of spawning ponds. Maximum depth of water in the pond was 76 cm. Milk cans with a capacity of 38 litres were submerged in 46 to 60 cm of water for spawning containers.

Domesticated brood stock are held in holding ponds with abundant natural food supplemented when necessary by feeding. In the south central United States the holding ponds are drained about the middle of April. Brood stock 1.3 to 4.5 kg in size are selected on the basis of their maturity and separated by sex. A male and a smaller female are then placed in each spawning pen. Spawning can be retarded by holding brood fish in water 18°C or lower.

Channel catfish spawn when the water temperature ranges between 18 and 22°C. When eggs are found the female is removed, the male being left to tend the eggs. Eggs hatch in 9 to 10 days. The fry are removed soon thereafter and transferred to troughs or nursery ponds. Fry stocked in nursery ponds are stocked in protective wire enclosures and fed for one to two weeks. The enclosure is then removed. Nursery ponds are so stocked that they will produce from 100,000 to 200,000 (10 cm long) fingerlings per ha. There is a mortality of about 35 percent when using this method to rear fingerlings from fry.

Clemens and Sneed (1957) and Sneed and Clemens (1960) reported on the use of fish pituitaries to induce the spawning of well-developed channel catfish in aquaria. They reported several advantages for this method: (i) the spawning period can be regulated; (ii) fish which will not spawn naturally sometimes can be induced to spawn; (iii) nursery ponds can be stocked with fish of a more uniform size; and (iv) the transmission of disease from the brood stock to the young can be minimized.

Using this method, females 0.45 to 1.8 kg produced on an average about 8,800 eggs per kg of body weight. Females of a larger size averaged 6,600 eggs per kg of body weight.

Sneed and Clemens (1959) later successfully used chorionic gonadotrophin to replace fish pituitaries. Since these hormones are readily available, this simplified the procedure.

Geibel and Murray (1961) in reporting on channel catfish culture in California found spawning pens unsatisfactory and pituitary extracts unnecessary. They successfully spawned channel catfish in brood ponds by using milk cans and terra cotta pipe (38 to 57 litres) coated with black asphaltum as spawning containers. Brood fish averaging 2.5 to 4.3 kg were sorted by sex and weight and stocked in 0.13 - 0.18 ha brood ponds in May at the rate of 225 to 235 per ha. Males were on the average slightly larger than females. Females comprised a little over half of the brood fish. The average spawning female produced approximately 8,800 eggs per kg of body weight.

Eggs were removed as soon as they were found and transferred to hatching troughs. Each spawn was placed in an individual hatching basket. A paddle mechanism that moved the water back and forth over the eggs for aeration was found to be essential, as were two daily malachite green flushes for control of fungus.

Eggs hatched in six to seven days. Fry were transferred when they were three days old to troughs with a 325 litre water capacity. About 30,000 fry were placed in each trough and thinned as they grew. Raw liver and trout pellets were readily utilized as feed. Parasites were controlled by weekly prophylactic treatments. Loss from egg to fingerling stage was approximately 40 percent.

Snow (1962) compared five methods of rearing channel catfish fingerlings to a minimum length of 7.5 cm. The methods were: (i) trough-raceway rearing, (ii) started in troughs and transferred to ponds when 19 mm long, (iii) fry stocked in ponds but held in protective boxes and fed for seven days, (iv) fry stocked in pond and fed, and (v) fry stocked in pond and not fed for three weeks. All experiments later received supplemental feeding. He concluded that recently hatched fry survived and grew well when stocked directly in ponds and protected as did fry stocked in troughs. Average production per ha with this method was 184,715 fish weighing 1,406 kg. The average mortality was 25.3 percent for the production period of 109 to 136 days.

Swingle (1957c; 1959) reported on experiments on growing channel catfish to a marketable size. Production of channel catfish and the gain in kg/ha/day rose from 1.59 to 4.81 with increasing rates of stocking from 2,471 to 12,355 per ha when fed. As the rates of stocking increased the average size of the catfish harvested decreased. Production ranged from 1,070 to 2,624 kg/ha depending on the rate of stocking and method of feeding (Table II). Maximum production of 2,423 kg/ha in 252 days was obtained from a stocking of 4,942 fingerlings per ha and supplementally fed pellets. Swingle (1954) had previously reported production of 80 to 103 kg per ha with fertilization only.

Growing ponds were fed at the rate of 2 to 5 percent of the total estimated weight of the fish when the water temperature was above 16°C. The maximum rate of feeding was limited to 33.6 kg/ha/day to prevent oxygen depletion. Feeding produced the best response when the surface water temperatures were above 21°C and comparatively little growth occurred below 16°C.

Pelleted[1] fish feed was found to be twice as efficient as dry mix meal. It was also found that when fish in growing ponds were fed, stocking in March and April resulted in lower conversion, lower cost per unit of fish produced, and higher average gains than stocking in autumn. The differences are due to the low water temperature during the winter and the amount of food fed to maintain body weight. The most efficient conversion obtained from spring stocking was S=1.24[2] with an average conversion of S=1.87 for seven experiments. Cheapest production could probably be obtained by holding the young catfish in nursery ponds until autumn, stocking the fingerling channel catfish in ponds in autumn and fertilizing only once or twice during the autumn months, then starting to feed the fish in the following spring. In this manner marketable-sized channel catfish can be produced in one year in growing ponds and the size can be controlled by the number stocked. The high cost of producing fingerlings prevents planned production of small catfish for the speciality trade.

Disease control has been stressed by all authors. The survival of channel catfish stocked in growing ponds ranged from 79.6 to 99.2 percent with effective treatment for parasites and diseases (Table II). The average survival for 13 populations was 94.6 percent.

Wild fish reduced the production of channel catfish and resulted in less efficient feed conversions. Largemouth bass fingerlings of equal or of a smaller size are usually stocked in growing ponds at the rate of about 125 per ha to control wild fish.

Nail (1965) investigated the protein requirements and Dupree (1960) the water soluble vitamins essential for growth of channel catfish. Other dietary requirements of channel catfish are largely unknown. In ponds natural food masks the deficiencies in the supplemental feeds being used to grow catfish. A better understanding of dietary requirements will be required if higher production is to be obtained at lower unit costs. Some work on the dietary requirements of channel catfish has been reported and additional work is underway at the present time.

Under certain conditions commercial catfish ponds might be harvested by angling. Prather (1959) discussed the partial harvest of channel catfish from growing ponds by angling. Anglers removed 62 percent of the fish stocked. The remaining fish were harvested by draining; the monetary return per unit of area was higher than that obtained from commercial sale of harvested fish.

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[1] Pellets are obtained by adding steam to the dry meal mix and forcing it through plates. A hard glazed feed of uniform size is then obtained which disintegrates slowly in water.

[2] $S = \frac{\text{Weight of feed added}}{\text{Total weight of fish produced by natural plus added feeds.}}$

Table II

Production(per hectare)of channel catfish in ponds stocked in the spring by fertilization and feeding (from Swingle,1959)

	Results in Pond No.						
	F-2	F-9	F-3	T-1	E-1	S-12	T-2
S Conversion	1.24	1.35	1.41	1.56	1.94	2.3	3.3
No. stocked	7,413	12,355	9,884	7,413	4,942	2,471	7,413
Average wt. g	6.0	6.4	6.0	2.3	2.3	2.3	2.3
Days in experiments	188	188	188	252	259	273	252
Total kg feed*	2,240	2,839	3,036	4,150	3,618	2,504	4,150
Recovered on draining							
Channel catfish (kg)	1,844.0	2,323.3	2,057.7	2,646.6	1,709.8	1,076.8	1,246.6
Other fish (kg)	74.4	120.1	16.9	0	207.2	0.3	116.5
Channel catfish survival percent	98.0	97.4	99.2	96.3	79.6	94.5	86.0

Albino channel catfish were compared with normal channel catfish by Prather (1961). There was no difference in the rate of growth although survival was less in the albinos, 81.1 percent versus 94.2 percent. These fish are of considerable interest because of their colour and are referred to as "golden" catfish.

The white catfish, Ictalurus catus (Linnaeus), was originally limited to the Atlantic Coast of the United States from New York south; however, it has been introduced elsewhere. Prather and Swingle (1960) investigated their value as a commercial species and reported that it is similar to the channel catfish except that white catfish gives higher survival. White catfish live exceptionally well under conditions of muddy water, hot weather and low oxygen. The white catfish has a slightly larger head which reduces the dressed yield on preparation for market. They concluded that this species appears to be a very promising pond fish especially for commercial production.

Another catfish which may be of value as a commercial pond species is the blue catfish, Ictalurus furcatus (LeSueur). The flathead catfish, Pylodictis olivaris (Rafinesque), is carnivorous, which will limit its value for commercial production. It may have value as a predator if stocked as an accessory species for control of wild fish.

Research on the nutrition and hybridization of channel catfish is in progress at the Fish Farming Experimental Station, Stuttgart, Arkansas and at the Southeastern Fish Cultural Laboratory, Marion, Alabama (Anon.,1965). At the end of 1964, 14 different hybrids had been produced. The channel catfish female x blue catfish male appeared to be the most promising cross and in a 225 day experiment outgrew the channel catfish and blue catfish by 15 and 65 percent respectively. Hybridization appears to give increased growth rates and an opportunity to control body shape.

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* All ponds fed pelleted feed except T-2 which was fed dry meal mix

4 CULTURE OF CRAYFISH (CRAWFISH)

Crayfish are a highly popular food in Southern Louisiana, along the Gulf Coast of the United States. Lambou (1965) estimated that fish dealers purchased 2,310,406 kg of crayfish valued at $911,000 in 1962, which were harvested from the Atchafalaya Basin Floodway. This basin is the major natural producing area. Thomas (1965) in describing crayfish production stated that the supply is often inadequate to meet the demand during late winter and early spring, the principal season of use.

Impounded rice fields often produce an occasional crop of crayfish; however, a method of cultivation to produce crayfish has developed within the last 10 years only. The Louisiana red crayfish, Procambarus clarkii (Girard) is cultivated almost exclusively.

There are two methods of cultivation, a rice - crayfish-pasture rotation, in which crayfish is a secondary crop, and culture in levied swamp-land where it utilizes land used for waterfowl hunting. In the 1959-60 season, Viosca (1961) estimated over 800 ha were being cultivated for crayfish. In the 1963-64 season, Thomas (1964) reported that crayfish were being cultivated on 1,900 ha of fields in rotation with rice. It is estimated that an equal area of swamp-land was also in cultivation.

The life history of the Louisiana red crayfish has been described by Penn (1943). Copulation may occur whenever males and females come together in shallow, warm water, most frequently in nature during the period July to October. Most of the eggs are laid in the months June to October with the peak occurring from the end of August through September. Eggs hatch in 14 to 15 days and the young are usually ready for independent existence five days later. Edible size may be attained by April.

Production of Louisiana red crayfish has been described by Broom (1961; 1963), Thomas (1965), and Viosca (1961). Pastures are ploughed in early spring. They are reploughed and rice planted about 1 May.[1] The rice fields are flooded from 15 May to 1 August. Usually there are sufficient crayfish in the field to serve as brood stock; if not, adults are stocked at the rate of 6 to 12 kg per ha after flooding. Irrigation of rice every other year provides enough moisture to maintain a resident propulation in most fields.

In August, the water is drained off the fields and the rice is harvested two to three weeks later. Some crayfish leave the fields; however, most of them burrow into the moist soil. The rice stubble resprouts about a week after harvest. Rice stubble and straw should then be reflooded to a depth of 15 to 45 cm.

The field remains flooded from September to June of the following year when the crayfish season ends and the field goes into pasture. Young crayfish can be found within three to four weeks after the autumn flooding. They feed mainly on the rice stubble, regrowth, and aquatic plants, although they are omnivorous. Growth to minimum edible size of 15 to 20 grams takes about 210 days; growth is most rapid in late winter and early spring.

Harvest can begin in December. The crayfish harvested in December, January, and early February are adults from the previous season or crayfish hatched in May or June, and weigh 40 to 45 g. Harvest continues until early June using traps and nets.

Fish are serious predators of crayfish. Draining rice fields eliminates most of the fish. If the field is reflooded from open water, the water supply should be screened. Various insecticides used on rice are toxic to crayfish (Muncy and Oliver, 1963). Insecticides are particularly important in rice-crayfish culture because the brood crayfish are present during the period the rice is growing. Crayfish can be reared in rotation with rice if the insecticides used are not toxic to them.

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[1] Dates may vary 10 to 15 days

Swamp-lands managed for crayfish are drained about early July to eliminate the fish and to allow wild vegetation to grow. If insufficient vegetation is present the land can be planted with legumes or grasses. Vegetation is reflooded soon after 1 September.

Crayfish are harvested with baited wire traps or mesh nets. A well-managed field will yield from 448 to 1,120 kg of crayfish per ha. Recent experiments at the Fish Farming Experimental Station, Stuttgart, Arkansas indicate that the above yields are feasible. Research on production techniques is continuing.

5 BRACKISH-WATER POND CULTURE

Systems of brackish-water commercial pond culture are well developed in many Asiatic countries. A number of preliminary experiments have been conducted in the United States which indicate that such a system on a commercial basis is feasible in this country. However, to our knowledge such a system has not been initiated in the United States.

Johnson (1954a) suggested a 7-9-0 (N-P_2O_5-K_2O) inorganic fertilizer for use in brackish-water ponds. This fertilizer was tested using striped mullet as a test fish (Johnson, 1954b). Average yields were increased through fertilization; however, the production of mullet was disappointing.

Ponds were stocked in December with 4,942 striped mullet per ha averaging 3 cm in total length. The ponds were fertilized each month at the rate of 224 kg per ha. Salinity during the experiment ranged from 7.6 to 35.7 ppt. At the end of 11 months the ponds were drained and the production of striped mullet was 112 kg per ha in the unfertilized pond and 132 and 143 kg per ha in the fertilized ponds. Average yield of mullet plus additional species that entered the pond as larvae was 263 kg per ha in two fertilized ponds and 173 kg per ha in one unfertilized pond. Lunz (1951) in South Carolina reported similar yields. His ponds were stocked by the immigration of various species into the pond when the inlets were open. One pond yielded an average of 280 kg of marketable fish per ha per year over a five-year period.

Yields of mullet could probably have been increased through the development of better fertilization techniques and improved methods of stocking with more adaptable species. However, striped mullet has a low market value in the U.S.A. and is not likely to make a suitable pond species for this reason. If brackish-water pond culture is to be successful, an intensive culture of marine species which bring better than average prices will be necessary.

The more promising of these appeared to be the white shrimp, Penaeus setiferus(Linnaeus) and the common pompano, Trachinotus carolinus (Linnaeus).

Johnson and Fielding (1956) have described the propagation of white shrimp in captivity. Sexually mature white shrimp that had been held or reared in ponds were successfully spawned four times over a two-year period in a concrete tank, 21.3 x 9.1 x 1.33 metres. The tank was filled with sea water which ranged in salinity from 31.5 to 37.0 ppt.

The resulting larvae were reared through the metamorphic stages to a pre-adult length of approximately 50 mm in the same facility. The maximum number of young white shrimp produced was 1,024 averaging 55.0 mm total length.

Water entering the spawning tank should be filtered to remove the planktonic algae and detritus which smothers the shrimp larvae. Filtering also removes small fish and other organisms which feed on the young shrimp. When the larvae enter the first feeding stages food can be introduced. Growth of juvenile white shrimp was extremely rapid. Captive postlarvae grew at the rate of 2.1 mm a day for a 24 day period in 1954, and 1.7 mm a day for a 28 day period in 1955.

Although sufficient young white shrimp were not propagated to support a commercial operation, it appears that with refinement such quantities could be readily obtained.

Experiments to determine the suitability of white shrimp as a pond species were begun in 1953 (Johnson and Fielding, unpublished data). One 0.05 ha pond was prepared for stocking by treatment with rotenone to remove the fish present. On 15 July 1953 it was stocked with 118,000 white shrimp[1] per ha. The small shrimp averaged 2.8 g each; their total weight was 341.6 kg per ha. The shrimp were fed with ground whole trash fish. The average daily rate of food consumption of small white shrimp in aquaria was 12.8 percent of their body weight. Initially the shrimp in the pond were fed 10 percent of their body weight per day. The feeding schedule was not rigidly adhered to since it appeared that the food was not being fully utilized.

The pond was drained approximately 4.5 months after stocking. A 33 percent mortality had occurred and 80,099 white shrimp weighing 1,147.3 kg per ha were recovered or a gain in total weight of 806.7 kg per ha. The S conversion was 7.05. Water temperature ranged from 18 to 32°C. Salinity ranged between 11.4 and 34.4 ppt.

In 1954, a 0.05 ha pond stocked at the rate of 180,000 shrimp per ha weighing 214 kg was treated in a similar manner. Approximately five months after stocking it was drained and 93,225 white shrimp weighing 1601.8 kg per ha were recovered. Average individuals increased in weight from 1.19 to 17.19 grams or over 1,300 percent.

The pond was restocked in November with 60,905 white shrimp weighing 1,059 kg per ha to determine winter growth. The pond was drained in May 1955 and 43,228 white shrimp weighing 1,266 kg per ha were recovered, showing a gain of 207 kg per ha with a mortality of 20 percent.

Oxygen depletion from overfeeding killed the shrimp in one pond. Spotted seatrout, Cynoscion nebulosus (Cuvier) entered two ponds through screen filters as larvae or fry. They seriously reduced the shrimp in one pond and eliminated them in another. In the pond where the shrimp were eliminated, 448 kg per ha of spotted seatrout were produced.

Lunz (1958) describes pond cultivation of shrimp in South Carolina. Ponds are allowed to stock naturally on incoming tides. Maximum production has been 182 kg per ha (Lunz, 1963a).

Lorio (1967) reported on attempts to grow brown shrimp, Penaeus aztecus Ives, in ponds where the salinity varied from 6.5 to 20.0 ppt. In 12 tests in 1962 and 1963 mortalities ranged from 73 to 100 percent. The production of brown shrimp was negligible.

Lunz (1963b) has described the use of teaseed cake (saponin is the active ingredient) to eliminate fish in shrimp ponds, a technique commonly used in Asiatic countries. Although effective, the cost of saponin prohibits its use in the U.S.A. He suggested the use of rotenone since at the minimum concentration required to kill fish shrimp were not affected.

Fielding and Johnson (unpublished data) investigated the use of common pompano, Trachinotus carolinus, as a pond fish. The common pompano appeared to meet the requirements for a commercial pond fish. Small pompano for stocking are available in adequate numbers in the coastal areas of the southern United States about early June with the number available gradually declining as the season progressed. Pompano are marketed in the round demanding an extremely high, stable price.

Ponds were stocked in June and July with pompano weighing 0.4 to 9.4 g at rates ranging from 1,324 to 4,942 per ha. The ponds were fertilized and ground whole trash fish were fed daily. The total amount of food fed daily depended on the readiness of the pompano to strike the ground fish thrown on the surface at each feeding.

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[1] All the juvenile shrimp used in the experiments were taken with a cast net from tidal creeks in the St. Augustine-Marineland vicinity with one exception. In 1954, 1,000 small shrimp that were spawned in the concrete tank were stocked in one pond.

The experiments were terminated at intervals of 65 to 133 days and the production of pompano ranged from 270 to 438 kg per ha. Maximum production of 413 and 438 kg per ha was obtained from ponds stocked with 4,942 pompano per ha, but in production for the shortest period, 84 and 65 days, respectively. However, the average size of the individual fish in these ponds was less than the average size of fish in ponds stocked at the lower rate and fed for longer periods. The largest fish averaged 268.0 grams each when recovered 108 days after stocking. The production of pompano per day ranged from 2.35 to 6.38 kg per ha, with an average of 4.03 kg per ha. The average S conversion was 6.1 and there seemed to be no significant differences between ponds.

Wild fish entered all ponds, except one, through a screen wire filter as larvae or fry. They were not a major problem because of the short duration of the experiments. Oxygen deficiencies and an excess of carbon dioxide resulted in higher than average mortalities. This condition was brought about by overfeeding plus the accumulation of organic material on the pond bottom from previous feeding experiments. Since fish kills of this type would be avoided by proper management, all of the freshly killed fish were considered as being alive at the termination of the experiment in calculating the mortality rate for the rearing period. Mortality for four experiments ranged from 13 to 23.9 percent with an average mortality of 18.7 percent.

Pompano can be sold legally in most states when they reach 22.5 cm fork length. Fish of this size weigh 280 g and can be readily marketed. However, the principal market demand is for pompano 340 g or larger.

Small pompano are available for stocking in early June. The temperature is suitable for growth from 1 June to about 1 December in the lower South Atlantic States and along the coast of the Gulf of Mexico, which would give a production period of 183 days. Earlier it was found that pompano held in ponds became lethargic when the water temperature dropped to 11°C and died when it reached 9°C.

If the average daily production of 4 kg per ha per day could be maintained for a period of 183 days, about 730 kg of pompano could be produced per ha per season. It is thought that this weight could be converted into usable pompano by correct rates of stocking. The culture of natural food prior to stocking small pompano could probably be used to increase the initial growth rate of the small pompano without danger of overfeeding.

There appear to be several marine species which would be suitable for commercial brackish-water pond culture. The white shrimp and common pompano, which have been discussed, appear to be most promising. Spotted seatrout grew well in ponds and fed readily on ground whole fish. They bring above average market prices and sufficient young are available for stocking. As was previously noted, 448 kg per ha of spotted seatrout were produced in one pond. The American oyster, Crassostrea virginica Gmelin, grew well in the fertilized ponds and could be produced in combination with any of the above species.

A commercial brackish-water pond culture system appears to have some unique requirements. It must be located in an area with a long growing season and near sources of larvae or small fish for stocking and trash fish. Trash fish for feeding may be obtained cheaply and in large quantities on the southern coast of the United States as a by-product of the shrimp fishery. Ponds must be constructed in tight soils so they can be drained and the bottom soils aerated. In order to control salinity, there must be a dependable unpolluted source of both fresh and sea-strength saline water. There are many estuarine areas in the United States along the lower South Atlantic and the Gulf of Mexico which appear suitable for the operation of commercial brackish-water pond culture systems.

6 CULTURE OF MISCELLANEOUS SPECIES

The common carp (*Cyprinus carpio* Linnaeus) was introduced in the Western United States in 1872 and in the Eastern United States in 1877 (U.S. Comm.Fish., 1880). They have since been stocked or have spread throughout much of the United States.

Swingle (1954) reported that with inorganic fertilization, 314 kg of carp per ha could be produced. If the ponds were fertilized and the fish fed 784,to 1,930 kg of carp could be produced per ha. The maximum production of carp was obtained at uneconomical rates of feeding. The common carp is one of the world's most important pond fishes; however, in the United States it enjoys a very limited market. Carp are not considered a desirable food fish probably because they contain many small bones. It is necessary to produce a large carp (2.25 kg and over) in order to market them readily. A buffalo fish of equal size has approximately three times the market value. The survival of carp is good, but they are less efficient converters of food than other species. Consequently, carp cannot be considered a desirable species for culture in the United States.

Swingle (1957d) reported on the use of herbivorous species of fish to control weeds in ponds. The common carp is known to ingest considerable quantities of plant material, although it is principally an insect feeder. However, the control of certain aquatic weeds by the common carp appears to be due in part to a muddying action while feeding. Swingle concluded that the Israeli strain of the mirror carp warranted further consideration, but the grass carp *Ctenoparyngodon idella* (Cuvier and Valenciennes) was the most promising.

The Israeli strain of mirror carp was successfully used to control aquatic weeds in a 1,200 ha acre reservoir (Mathis, 1966). To control the weeds they were stocked at the rate of 120 per ha over a two and a half year period. The reservoir contained an established fish population and the Israeli strain has not successfully reproduced. However, it has contributed to both the sport and commercial fishery.

Avault (1965a) tested eight species of fish to determine their effectiveness in aquatic weed control. The Congo tilapia, *Tilapia melanopleura* Dumeril, grass carp and the Israeli strain of the mirror carp showed the best potential. Grass carp were brought into the United States in 1963 to determine their effectiveness in aquatic weed control. Avault(1965b) found that grass carp 30 to 40 cm long, stocked at the rate of 1,700 per ha in preplanted pools, would eliminate all aquatic weeds in six weeks. Although all 12 plants in the pools were eliminated, the soft plants were consumed first. Grass carp, averaging 30 to 40 cm in length, were also effective in controlling needle rush, *Chara*, and pondweeds in one to three months when stocked at the rate of 50 to 100 per ha.

Stevenson (1965) stated that grass carp survived in water temperatures from near freezing to 31.6°C. Growth of the fish in Arkansas compared favourably with that reported for semitropical countries. At the end of 12 months they averaged 0.37 kg and at 18 months, 1.8 kg. Grass carp appeared to prefer commercial pellets, fish meal, zooplankton, and other foods over aquatic plants. Although grass carp appears to be the most promising herbivorous fish, Stevenson questions whether they will remain strictly herbivorous when stocked in ponds containing a variety of foods. Further experiments on the grass carp will be necessary to determine their value in mixed populations.

Four species of tilapia have been investigated in the United States to determine their value as a pond fish and/or for weed control. The Congo tilapia previously mentioned has shown the best potential for weed control (Avault, 1965a). *Tilapia heudeloti* Dumeril fed on higher plants but no significant control was obtained. Java tilapia, *T. mossambica* Peters controlled *Pithophora* sp., a filamentous alga, when stocked in ponds at the rate of 2,500 to 5,000 per ha but it did not control higher plants. Nile tilapia, *T. nilotica* Linnaeus, controlled *Pithophora* sp., when stocked at the above rates and in addition reduced some higher plants.

Swingle (1958; 1960) evaluated the Java and Nile tilapia as pond fishes in Alabama. Highest production was obtained by stocking brood tilapia, fertilizing and feeding. When Java tilapia were raised alone in ponds in this manner, total net production ranged from 1,977 kg per ha in 154 days to 4,702 kg/ha in 196 days. The percentage of usable fish by weight ranged from 7.2 to 30.6, except in one experiment in which a small number of adults were stocked. The S conversions were usually less than 1.5.

Production of the Nile tilapia was similar in quantity with a maximum net production of 4,483 kg/ha. The two species appeared equally efficient in utilization of feed. The Nile tilapia appeared less prolific and consequently produced higher percentages of usable fish.

The percentage of usable tilapia was increased by the introduction of predaceous fish or by stocking with fingerlings. Java tilapia fingerlings stocked at rates of 10,000 to 50,000 per ha and fed gave a production of 864-3,629 kg/ha. The percentage of usable fish by weight ranged from 67.7 to 99.7.

Fingerling Nile tilapia stocked at rates of 20,000 and 40,000 per ha and fed produced 2,822 and 3,696 kg per ha respectively. The percentage of usable fish by weight was 98.5 for the lower rate of stocking and 91.9 for the higher rate. S conversions were 1.8 for the lower stocking rate and 1.35 for the higher rate.

Kelly (1957) reported that Java tilapia ceased feeding at temperatures below 15.5°C and died at 9°C. In ponds small Nile tilapia, less than 15 cm in length, died at a water temperature of 9°C (McBay, 1961). Mortality in the larger fish occurred progessively with decreasing water temperature. Some 22.5 to 27.5 cm fish survived 3.6°C for a short period of time.

Nile tilapia have been stocked in phosphate pits in southern Florida to determine their potential as a sport and food fish (Crittenden, 1965). They overwinter in this area, but no detailed reports on the results of the experiment are available.

Tilapia do not appear to be suitable for commercial culture in this country at this time. Of the four species tested in the United States the Nile tilapia is the most promising one for commercial production. In addition to the problem of small size and difficulty in overwintering, it is doubtful if there would be widespread consumer acceptance at a desirable price.

The paddlefish, Polyodon spathula (Walbaum) has been considered for commercial pond culture (Meyer and Stevenson, 1962). It is a commercial species found in the Mississippi-Missouri River drainage and from Alabama to Texas. Paddlefish attain a large size, the flesh is highly palatable and the roe can be used for the production of caviar. Food habits indicate that it is adapted for the utilization of natural foods available in ponds and reservoirs.

7 DISCUSSION

Species suitable for commercial pond culture should meet certain criteria, viz: (i) reproduce only under controlled conditions, or be species in which reproduction can be controlled through stocking; (ii) be a rapid and efficient converter of food stuffs; (iii) be non-competitive with accessory species; (iv) produce the highest return per unit of area, and (v) be acceptable to the general public. Channel catfish, white catfish, buffalo and other species reproduce only under controlled conditions. Reproduction of southern brown bullhead and Nile tilapia and other species can be controlled through stocking. The control of reproduction through stocking is not always advantageous since unusable fish of a small size might be produced.

The channel catfish is the most efficient species tested in the United States. S conversion for the production of usable channel catfish is 1.2 to 3.0 (Table III). Production of 2,650 kg per ha has been reported; however, in experiments conducted by Swingle (unpublished) production has exceeded 3,400 kg/ha.

Table III

Comparison of maximum productions, most efficient conversions and rates of gain for several species tested in Alabama (Swingle, 1960)

Fish production per ha per season (March-October) with fertilization and feeding

Species	Total kg	Gain kg per day	S conversion Total fish	Usable fish
Southern brown bullhead	1,008-1,344	4.5-5.6		2.0-2.5
Channel catfish	2,243-2,647	8.0-12.0		1.2-3.0
Common carp	1,120-1,456	5.6-6.7		2.2-2.6
Java tilapia	2,010-4,916	11.0-29.0	0.4-1.1	1.2-5.0
Nile tilapia	2,666-4,483	10.7-23.5	0.7-1.4	1.4-2.7

No species of commercial pond fish is truly non-competitive. There is some competition, although the degree of competition may be small. It is thought that other species such as buffalo fish can be reared with channel catfish and yield higher returns. This idea has not been tested. Of the commercial species tested in the United States the channel catfish has the best consumer acceptance and highest market value. The channel catfish must be the principal species in any fresh-water commercial pond culture system if it is to yield maximum returns. This does not preclude the use of buffalo fish as an accessory species if the return from the buffalo fish compensates for the possible reduction in production of channel catfish. Grass carp or some other suitable herbivorous species can also be utilized as an accessory species for weed control. A predaceous species should be utilized to control wild fish.

In special situations other cultural systems might be utilized. Buffalo fishes will probably be produced in rotation with crops where labour is not available for the intensive culture of channel catfish.

Crayfish culture utilizes rice and swamp-lands. On rice-lands it is a secondary crop and on swamp-lands it utilizes lands used for waterfowl hunting. Brackish-water culture if it develops will occupy lands which are not suited for the production of fresh-water species. These two systems therefore are non-competitive with each other and the culture of buffalo fishes, catfishes or miscellaneous species.

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NEW SYSTEMS AND NEW FISHES FOR CULTURE IN EUROPE

by

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Abstract

Supply of water to fish ponds by pumping has proved economical in commercial fish culture. Adequate supplies of water during winter can be ensured by pumping from deep storage tanks.

It has been possible to reduce the cost of construction of carp ponds by the use of standardized structures, like sluices which can be pre-fabricated in large numbers at relatively low cost. The new layout of carp farms in Hungary, which has proved very efficient for the mechanization of operations is described.

Culture of predatory and herbivorous fishes has proved successful. The artificial propagation of the pike, pike perch and sheatfish are described. The culture of species that compete with carp for food has diminished in Europe.

The Chinese carps (*Ctenopharyngodon idella*, *Hypophthalmichthys molitrix* and *Aristichthys nobilis* are now being cultured in the U.S.S.R., Rumania, Hungary, etc., and their importance will increase in the future. Their artificial propagation has been accomplished.

NOUVELLES TECHNIQUES PISCICOLES ET NOUVEAUX POISSONS D'ELEVAGE EN EUROPE

Résumé

L'alimentation en eau des étangs par pompage s'est avérée rentable en pisciculture commerciale. En hiver, des quantités suffisantes d'eau peuvent être pompées dans des réservoirs profonds.

Le coût de construction des étangs de carpiculture a pu être abaissé grâce à l'emploi d'éléments standard, comme les écluses, qui peuvent être préfabriqués en grande série pour un prix de revient relativement faible. L'auteur donne une description de la nouvelle disposition des installations adoptée pour les exploitations de carpiculture en Hongrie, disposition qui facilite considérablement la mécanisation des opérations.

L'élevage de poissons prédateurs et herbivores a donné de bons résultats. Une description est fournie des méthodes employées pour la propagation artificielle du brochet (Esox lucius), du sandre (Lucioperca lucioperca) et du glane (Siluris glanis). L'élevage des espèces qui entrent en compétition avec les carpes pour la nourriture est en régression en Europe.

Les carpes chinoises (Ctenopharyngodon idella, Hypophthalmichthys molitrix et Aristichthys nobilis) sont maintenant élevées en U.R.S.S., en Roumanie, en Hongrie, etc. et leur importance va augmenter à l'avenir. La propagation artificielle de ces espèces a pu être réalisée avec succès.

PECES Y PROCEDIMIENTOS PISCICOLAS NUEVOS EN EUROPA

Extracto

Llenar de agua los estanques por medio de bombas ha resultado ser económico en la piscicultura comercial. Durante el invierno se puede asegurar el suministro suficiente de agua bombeándola desde depósitos profundos.

Se ha conseguido reducir el costo de construcción de estanques para carpas empleando estructuras normalizadas, a modo de esclusas, que pueden prefabricarse en grandes cantidades y a un costo relativamente bajo. Se describe el nuevo trazado de granjas carpícolas que, en Hungría ha resultado eficacísimo para la mecanización de las operaciones.

Ha sido satisfactorio el cultivo de peces predadores y herbívoros. Se describe la propagación artificial de lucios, luciopercas y siluros. El cultivo de especies comestibles competidoras de la carpa ha disminuído en Europa.

Las carpas chinas (Ctenopharyngodon idella, Hypophthalmichthys molitrix y Aristichthys nobilis) se cultivan hoy en la U.R.S.S., Rumanía, Hungría, etc., y en lo futuro tendrán más importancia. Su propagación artificial se ha conseguido satisfactoriamente.

1 NEW SYSTEMS OF CARP CULTURE

The history of breeding carp in Europe goes back several hundred years. Its present methods have been developed since the end of the last century.

Carp ponds are generally set up in places where there is no water supply problem, i.e. the ponds can be filled and drained at the most appropriate time for fish production.

1.1 The siting of fish ponds

There has been a great deal of discussion about the siting of fish ponds. Several authors (especially in Hungary) maintain that the great expense of constructing a fish pond can be more easily recouped if the ponds are built on good soil. This standpoint can no longer be held and now ponds all over Europe are built in places where the soil is not suitable for agriculture, thus bringing new land under intensive cultivation where formerly there was no, or little, yield.

1.2 Water supply

In former times, and to some extent even today in several countries of Europe, fish ponds were constructed in places where the ponds could be fed with water from streams and canals and also drained by gravitation. New possibilities now arise from the development of pumping techniques, for now we have at our disposal electric and diesel pumps which are able to raise water in great quantities, and thus ponds can be operated in places distant from water supplies.

In Hungary more than half of our ponds (100,000 ha) are continuously, or in dry weather periodically, fed by pumped water. The biggest fish farms without exception use only pumped water. In most places pumping is done in two stages, water is pumped first into a large canal system from the river and during the second stage from the canals into the ponds.

The normal water requirements for operating fish ponds built on porous soils in Hungary are as follows:

	For filling (m^3/ha)	For maintenance of water level (m^3/ha)
Non-porous soil	10,000	4,000
Moderately porous soil	13,000	6,000
Very porous soil	16,000	10,000

Electricity is cheaper than diesel fuel for pumping. When fish are produced on a large scale the cost of pumping is negligible (in Hungary 0.3 - 0.45 U.S. cents/m^3). The capacity of pumps used is 350-500 l/sec. and several of them can be used together, according to the size of ponds.

1.3 Water supply for wintering basins

In places where the ponds are fed by pumping and there is no fresh canal water available during winter, the wintering basins are constructed next to a large pond which provides fresh water throughout the winter months. The reservoir is usually a big pond sited rather low, where fish is grown in summer. The water drained from the wintering basin is collected into a small lake or canal from where it is pumped back to the pond. Using this method the wintering basins can be reliably supplied with fresh oxygenated water and in European climatic conditions a greater majority of fish can be saved.

1.4 Pond design to facilitate harvesting the fish crop

Fish ponds in Europe fall into two types:

(i) Dammed valley ponds, where in gently sloping valleys the dam is built at a right angle to the direction of the slope. These ponds have no embankments on the sides. This is the older type of fish pond.

(ii) Ponds with a circular dam on flat land. These ponds have artificially made dams on all sides.

In the first type the size of pond is determined by environmental conditions and the sluice gate is built at the lowest point of the pond. The size of ponds on flat land can be determined at will. Taking economic factors into consideration ponds should be built just large enough for fish production (50-200 hectares). Since the ground in such cases has no appreciable slope, the draining sluice gate can be located anywhere in the drainage canal. The channel where fish are collected (the "fishbed") should be a 0.5 - 1 m deep and 10 - 16 m wide ditch inside the draining sluice gate where the fish can gather during draining. The "fishbed", excavated artificially, does not have a long life, especially in large fish ponds, as it gets filled up with mud and in the course of a couple of years it simply disappears. It requires frequent cleaning which is extremely expensive because of the lack of suitable dredging machines. Manual labour can only be used when the pond has been completely drained and is dry. Because of this, ponds in Hungary with a circular dam built on flat land - most of our ponds belong to this type, and new ponds are built only on flat land - must have a central fish collecting bed external to the ponds which surround it in a semi-circle or horse-shoe and are divided from it by a dam. The water is led into the fishbed from each pond through a sluice gate. Originally this sluice gate was the ordinary sluice gate of the pond but nowadays these sluice gates can be opened to let boats through. This central, external fishbed has a very large sluice gate through which the water can be drained from the fishbed into the drainage system.

With this system there is no need for each pond to have a separate fishbed. The draining of the pond is regulated by the sluice gate of the external fishbed. The sluice gate between the pond and the external fishbed should be fully open in order not only to make the fish feel the lowering of the water level but also to help them to find the direction of the flow in which they swim to the external fishbed through the open sluice gate. Thus, even as many as nine ponds, which are drained and fished successively, can drain into one external fishbed. Having an external fishbed has proved useful because the various phases of fishing can be mechanized.

An external fishbed is 15 - 25 m wide and depending on the number and size of ponds belonging to it, can be 100 - 500 m, in exceptional cases 1000 m, in length.

The advantages of having a central, external fishbed can be summed up as follows:

(i) this does not get filled up with mud (or this process takes a very long time);

(ii) maintenance work can be done during summer;

(iii) fishing is concentrated in one place facilitating mechanization. The fishing place can be concreted and the transport of fish made easier;

(iv) the wintering basins can be built near the external fishbed, thus reducing transportation costs;

(v) if the sluice gate of the central fishbed is made big enough for the passage of boats, then feed, manure, etc., can be transported by boat from adjacent stores.

The main feature of this new type of fish farm with a circular dam on flat land is the central, external fishbed. All store houses, loading sheds, basins for soaking fish feed, etc., are built around it and the wintering basins are also nearby. The fishbed is surrounded by production ponds arranged in a semi-circle.

2 NEW SPECIES OF FISH FOR POND CULTURE

In artificial fish ponds in Europe where the water reaches the temperature of 25 to 30°C, the main species cultured is carp (Cyprinus carpio). Other species can be bred together with carp, and these generally add to the fish crop, to a greater or lesser extent. This is because the fish food production in ponds is fairly complex, and carp only utilize some of the foods available. The various species utilize the different foods more fully, even if they compete with carp to some extent for certain types of food. Thus the overall utilization of the natural resources of ponds is considerably increased.

Rearing several species together in many cases produces a positive "co-existential" effect (for example carp and tench or carp and herbivorous fishes).

The species grown with carp can be divided into the following groups:

(i) predatory fishes
(ii) fishes competing with carp for food
(iii) herbivorous fishes
(iv) other animals

2.1 Predatory species

Rearing predatory fishes together with carp has been made necessary by the fact that the eggs, larvae, fingerlings and in many cases even sexually mature specimens of undesirable fishes may get into the ponds with the water supply, despite careful filtration through a fine mesh. These fishes consume carp food, thus interfering with carp production. Generally they are small fishes and their flesh is of no value so the food that they consume is wasted, and they often eat the prepared feed given to the carp as well as the natural food.

The predatory fish thus have a twofold use, they decrease the number of fish which compete with carp for food, and they transform fish flesh of no value into valuable meat. Certain species of predatory fish also eat other animals (such as frogs, etc.,) which are likely to frequent fish ponds.

It is often necessary to keep sexually mature carp in the ponds, and the predatory fishes then consume the carp fingerlings produced by wild spawning.

Predatory fish also render a "sanitary service" in eating underdeveloped, sick or weak carp. The predatory fishes are either the same size or smaller than the propagated fishes, so are not harmful to carp.

Predatory fish cultured together with carp in Europe include pike (Esox lucius), pike-perch (Lucioperca lucioperca), sheatfish (Siluris glanis), black bass (Micropterus salmoides) and rainbow trout (Salmo gairdneri) (not considered here).

2.1.1 Pike (Esox lucius)

Rearing pike in fish ponds is less common now than formerly. Pike feed primarily on small fish (Cyprinids) of little value, but they should only be stocked in ponds where the extermination of other predatory fishes (pike-perch, sheatfish, black bass) cannot be solved by other means. In many fish ponds fingerlings or one-summer-old pike are produced to populate natural waters and are sold mainly to angling clubs. According to Herms (1962) 2,000-2,500 pike a few weeks old may be stocked per hectare and about 2 to 5 percent of them survive until the autumn.

The principles of breeding two-summer-old pike are the same as those for other predatory fishes. Pike's oxygen consumption is somewhat greater than that of carp, their transport and wintering is similar to that of pike-perch.

The method of reproducing pike artificially has been fully worked out and applied all over the world; several books deal with this problem.

2.1.2 Pike-perch (Lucioperca lucioperca)

Pike-perch is a particularly suitable predatory fish for carp ponds as its gullet is relatively narrow, and the carp fingerlings grow fast and are soon too big for them. Pike-perch consume almost all the small fish and the fingerlings which come from wild spawning, using 5-10 kg fish to produce 1 kg pike-perch flesh. This flesh is valuable as it is white, not very bony and not fat. The problem of their reproduction has been solved. The only drawback to rearing them is that they are delicate, which makes catching and transporting them complicated. The oxygen consumption of pike-perch is much greater than that of carp and when caught they are easily drowned in water muddied by carp. When handled their skin often develop fungal infections from which they die.

Pike-perch are propagated in almost every part of Yugoslavia and Hungary but their use is not so widespread in Germany, Poland or Czechoslovakia. In East Germany the rearing of one-summer-old pike-perch fingerlings is of great importance and these fish are later stocked in natural lakes.

Many fish farmers consider that this fish does not grow well in muddy, shallow waters, because their natural habitat is in deeper water, over pebbles or sand. But Hungarian experience shows that they can be propagated with good results in any kind of artificial carp pond (Unger, 1939a; Ribianszky and Woynarovich, 1962).

2.1.2.1 Growth

Growth rate depends on the amount of food available, but a one-summer-old fish is 12-25 cm, 30-100 g. In Germany one-summer-old specimens of 6 to 10 cm long are aimed at in order to produce as many fingerlings as possible (Steffens, 1960b). Two-summer-old specimens are 30-40 cm (200-500 g) and three-summer-old specimens 37-55 cm (500-1500 g). They reach sexual maturity at three years of age.

2.1.2.2 Stocking

Carp ponds can be stocked with fertilized eggs and one and two-summer-old pike-perch. According to the food available, 1,000-2,000 eggs, and 50-100 one-summer-old or 30-60 two-summer-old fish can be stocked per hectare of pond surface.

2.1.2.3 Treatment during breeding season

Pike-perch need no special treatment during the breeding season, but fertilization may prove necessary to increase the food supply in the ponds where fingerlings are reared, (Wundsch, 1963).

2.1.2.4 Fishing

Pike-perch are quick to notice when the water is being drained and the first to gather in the fishbed. If the water is drained quickly they try to escape with the water and fingerlings can easily be caught by means of a trap-box placed behind the sluice gate. The pike-perch must be immediately separated from the carp caught in the net, and should be kept in a holding net in fresh, clean water. When caught they should be put into a bucket with their heads down and so transported into the holding net (Ribianszky and Woynarovich, 1962).

2.1.2.5 Transport

In cold water (0-5°C) about a quarter as many, and at a temperature of 10-15°C about one tenth as many pike-perch can be transported together as in the case of carp. Fingerlings intended for later breeding, and spawning specimens, need special care and treatment during transport.

2.1.2.6 Storage, wintering

When stocked for a long time or during winter, pike-perch must be graded according to size and put into wintering basins. There is a danger of cannibalism. Food must be provided for them in the form of small fish appropriate to their size; 150-200 kg fish food is enough to last 100 kg pike-perch the whole winter.

2.1.2.7 Spawning and obtaining fingerlings

Reproduction in fish ponds was worked out in Hungary at the end of the last century (Répássy, 1914; p.192). Spawning takes place in mud-free wintering basins of 300-1,000 m^2 surface area and 1.2 - 1.8 m deep. Nests are placed in these basins according to the number of pike-perch pairs. The nests should be made of willow and alder roots, collected in winter. (Crochus, an Hungarian fish breeder living in France successfully uses nests made of stiff plastic fibres). The willow roots or other nest-making materials are tied with string in thin layers onto a 50 x 50 cm frame. The material is fastened to a wire sieve, ballast is fixed to the bottom of the nest, and four wires from the corners reach to the water surface so that the nest may be lifted out onto the bank at any time. These nests lie on the bottom of the wintering basins. One nest and one spawning pair may be stocked for every 2 to 5 m^2 basin surface.

Flooding the basin with water and placing the nests and spawning pairs are done when the water temperature is 8 to 9°C and a considerable drop in temperature is unlikely. Pike-perch can be induced to spawn in smaller concrete basins if they are hypophysed according to the method of Tölg and Antalfy (in litt.). An extract of four pituitary hypophyses in a physiological salt solution, is injected into the back muscles of 2-25 kg females; two pieces of hypophyses are used in the males. This injection stimulates spawning which takes place in the nests in one to three days. The injected and spawned specimens must be sold as they cannot be used any more for breeding (Tölg in litt.).

The eggs can be transported for several consecutive days if properly packed in crates lined with wet moss and ice. When transported for some hours only it is enough to cover the nests in a basket with wet moss or a wet cloth.

The nests should be suspended in ponds to a depth of 0.5 m with the covered egg surface downwards. Eggs can be protected from harmful fish with a fine mesh (Antalfy and Tölg, 1965).

One pike-perch nest contains about 20-200,000 eggs. About 1,000-2,000 eggs can be stocked per hectare, together with the one and two-summer-old carp, and also with denser populations of one-year old carp fingerlings. In many ponds (both in Hungary and in East Germany) fingerlings can be obtained by natural spawning by stocking breeding pike-perch (Wundsch, 1963). One female and one or two pike-perch are stocked per hectare. If the pond is fertilized, an average of 14,000 - 20,000 pike-perch fingerlings 6 to 10 cm long can be caught with the help of a trap-box from a carp pond.

Eggs spawned in artificial nests can be reared until they are hatched in spray-chambers (Woynarovich, 1960). In these spray-chambers the eggs in clusters in the nests grow in a fog-like spray produced by spray-heads similar to those employed in plant protection using water at one to four atmospheres pressure; for this method electricity is needed. Thirty to sixty nests can be located in 1 m^3 of sprayed space, and at 10°C the eggs hatch in 11 days.

2.1.3 Sheatfish (Silurus glanis)

Breeding sheatfish in ponds was first developed in Hungary, then spread to Yugoslavia and Czechoslovakia, the only countries in Europe interested in growing this species.

Propagating sheatfish in carp ponds does no damage to the carp. The sheatfish feed on small fish, frogs and tadpoles and grow quickly. The problem of how to produce them in fish ponds and rear the fingerlings has been solved. They can be caught and transported together with carp, as they are not very delicate. Their oxygen consumption is somewhat less than that of carp and they are resistant to diseases except gill parasites. The disadvantage is that when very young (10 to 20 days old) they develop cannibalistic habits.

2.1.3.1 Growth

Sheatfish grow well and reach a weight of 50-100g by the end of the first summer. When they are two summers old, well-fed specimens may reach a weight of 1,000-1,400 g, or if densely stocked, 500-1,000 g. Three-summer-old specimens may reach 1,500-2,500 g, depending on the food supply.

2.1.3.2 Stocking

Young sheatfish fingerlings, after hatching, are best reared in nursery ponds until they reach a size of 4 to 6 cm. As many as 1,500-2,000 per hectare of these can be stocked. Autumn catching is estimated to take 50-80 percent of this stock. Eighty to 150 one-summer-old fish and 35-60 two-summer-old fish may be stocked per hectare, the number depending on the "weed-fish" available as food.

2.1.3.3 Breeding treatment

Sheatfish do not need special food or special treatment during the breeding season. The fingerlings are fed on artificial food.

2.1.3.4 Fishing

Neither fingerlings, nor adults which are ready for sale need any special treatment; they can be caught together with carp.

2.1.3.5 Transport

This does not differ in any way from that of live carp, although the oxygen consumption is somewhat less than that of carp.

2.1.3.6 Storage, wintering

For short-term storage a holding net is sufficient. In storage basins only sheatfish of the same size can be stocked together because of cannibalism. If they are stored for a longer period of time, food must be provided for them. This should consist of small fishes of the proper size. About 150-200 kg food fish are needed per 100 kg sheatfish for the winter lasting five months.

2.1.3.7 Obtaining fingerlings by artificial reproduction

Sheatfish spawn without any difficulty in storage basins which are 300-800 m^2 surface area and 1.0 - 1.5 m deep if proper nests are built for them, the depth and temperature of water supply of the storage basins are appropriate, and the sex ratio of breeding fish is about 1:1.

The mature sheatfish should be sexed and segregated when the temperature of the water reaches 12-14°C. The female has a round (bulging) belly and the genital papilla is wide; the male is slenderer, the belly does not bulge and the nipple-like genital process is narrow and pointed.

Sheatfish nests should be made of the roots of willow and alder trees collected in winter. Twigs of pine and thuya can also be used. This is a so-called "tent-nest": three sticks (1.8 - 2 m) are stuck into the ground in the shape of an equilateral triangle and their upper ends tied together. The tree roots or twigs are fastened with wire on this tent frame. In several fish farms these frames are prefabricated, but the roots or twigs have to be renewed every year. A "carpet" made of bulrush and reeds should be placed under these "tents", in order to collect the falling eggs so that they are not lost in the mud.

Two to four such "tent-nests" can be located in one storage basin and the number of sheatfish pairs stocked should also be the same. The water in storage basins should be 1 - 1.2 m deep. When the temperature of the water reaches 20°C and the weather is improving, the nests should be placed in the basins which should be filled with water and the sheatfish pairs introduced the same day. They generally spawn late in the evening and at night. Their restiveness around the nests marks the beginning of spawning; they start clearing the willow roots with their tails, hiding in the nests, and chasing one another around.

The nests should be checked daily from a small boat. Nests with eggs should be taken out of water and twigs with eggs on them taken off to the hatching place.

Fresh eggs can be transported in wet moss or a wet cloth without considerable loss within 6-12 hours after spawning. Hatching can take place in hatching crates or Zuger jars. Hatching crates should be about 150 cm long, 50 cm wide and 60 cm deep and covered with a lid. The sides and bottom should be made of fine perlon sieve of 0.5 - 0.8 mm mesh. The twigs with eggs on them should be hung on wires in the crates. The crates are put into the storage basins intended for rearing the fingerlings, and should be fixed next to the inflow pipe with sticks; 30,000 - 50,000 eggs can be put into one crate.

Twigs covered with eggs can also be put into Zuger glasses. The eggs hatch in about two and a half days at a temperature of 20-22°C.

Freshly hatched sheatfish larvae are yellow in colour and gather in groups; they start eating four or five days after hatching when about 12 mm long. A large supply of plankton should be introduced in the crates during this period; 10-12-day old sheatfish may also be fed with artificial food consisting of ground fish, and scrapings of liver and spleen. This mixture can be put into the crate on a black tray or smeared onto the side of a flower pot.

Sheatfish larvae hatched in Zuger jars can be stocked directly to nursery ponds. Bundles of willow twigs, reeds and porous bricks should be put into the ponds for fingerlings to provide the hiding places which they need. Feed is also placed there, near the hiding places, either on a black tray or spread on a flower pot.

Five to seven thousand sheatfish fingerlings can be stocked in nursery ponds for every 100 m^2. Only fingerlings of the same size can be stocked together and bigger ones should be separated as they become cannibalistic.

Food can be provided for sheatfish fingerlings by spawning several carp, tench or silver crucian in nursery ponds, or stocking carp fingerlings.

Sheatfish stay in nursery ponds until they reach the age of 30 to 35 days and a size of 5 to 6 cm, when they are introduced in a bigger pond. Their food can be provided by spawning carp and tench in the pond 15 days before stocking. Ponds may be stocked with 1,500 to 2,000 fingerling sheatfish per hectare for rearing until autumn.

2.1.4 Black bass (Micropterus salmoides)

In Europe black bass are propagated in fish ponds. The advantages of breeding this fish are the same as for pike-perch, but it is not as sensitive as pike-perch. Since the problem of reproducing it successfully has not yet been solved, a sufficient number of them for stocking is not available anywhere.

Reproduction takes place naturally by stocking breeders in carp ponds and 100 - 200 fingerlings per female can be expected in the autumn. Artificial or semi-artificial means of breeding black bass should have to be evolved or the American method of propagating this species adopted and extended in Europe.

2.2 Species competing with carp for food

Tench, silver crucian carp, peled whitefish, whitefish and striped mullet, all compete with carp for food. Nevertheless the following factors favour rearing them together with carp: their habitat is different from that of carp and they feed on food not satisfactorily utilized by carp, so they contribute to the fuller utilization of ponds, and they increase the variety of fishes available for sale. On the other hand, they do decrease carp production to some extent, they make fishing more complicated as the fish must be sorted, and they can spread contagious diseases (Schäperclaus, 1961). But on the whole the economic advantages outweigh the disadvantages.

The peled whitefish (Coregonus peled) was introduced from Siberia and has been propagated during the last ten years in fish ponds in the European part of the Soviet Union. It is reared with good results in carp ponds, both in the North and in the Ukraine, and has been introduced experimentally into East Germany. It feeds primarily on zooplankton. In Soviet Latvia they did well at a temperature of 21-26°C, but this is not really a warm-water species.

Another whitefish (Coregonus lavaretus marena) from the Madü-See has also been used successfully in ponds in Czechoslovakia, chiefly in deep dam-valley ponds. Though it withstands a temperature as high as 25°C tolerably well, this species can only be propagated in cold water, so is not considered further here.

2.2.1 Tench (Tinca tinca)

Tench is one of the most important secondary fishes of European fish ponds and in certain areas there exists carp-tench ponds (Schäperclaus, 1961). However, rearing this species is on the decline, and now only incidental, because of the development of large-scale carp production and also because of the lack of man-power. The advantages of breeding tench in fish ponds can be summed up as follows:

(i) when searching for food, tench grub up mud deeper than carp and so increase the production of the ponds;

(ii) tench only overlap in food habits with carp to a limited extent and utilize a great deal of natural food stuffs left untouched by carp;

(iii) tench consume the excrement of carp fed on artificial food which contains a great deal of undigested or half-digested food stuffs;

(iv) its oxygen consumption is less than that of carp;

(v) it sells for 20 percent more than carp.

The disadvantages are:

(i) an overpopulation of tench decreases the carp crop;

(ii) its skin easily gets bruised;

(iii) tench reach maturity when three summers old and can be of very small size;

(iv) many remain in the mud when the pond is drained.

2.2.1.1 Growth

From the second year males and females grow differently, the females growing 50 to 60 percent faster than males. Their growth depends on the number of fish stocked and food available. At the end of one summer they range from 2 to 10 g weight, of two summers from 25-150 g, of three summers from 170-450 g, and four-summer-old specimens can attain a weight of as much as half a kilogram or more. In the market two and three-summer-old tench (120-300 g in weight) are very much in demand for sale in portions. The rearing of tench of more than 300 g does not seem to be economic. Fast growing new types can and should be bred, using modern methods for selective breeding and for improving the species.

2.2.1.2 Stocking rate

Only carp and tench of the same age should be stocked in ponds. Twenty to thirty one-summer-old tench should be stocked together for every 100 carp of the same age. In the third summer only 20 two-summer-old tench may be stocked for every two-summer-old carp. In practice a yield twice or in exceptional cases, three times as much weight as the original stock can be expected. The crop per hectare may be as much as 50-80 kilograms.

2.2.1.3 Fishing and transport

Tench do not collect in the fish-bed as easily as carp and young ones in particular (one and two-summer-old fish) are left in the mud. So the water must be drained off very slowly and carefully, and the drain canals of tench ponds kept clean. Treatment during fishing is the same as for carp. Tench can be transported in the same way as carp.

2.2.1.4 Storage, wintering

One and two-summer-old tench can be kept together with carp of the same age. Fifty to 150 one-summer-old tench can be wintered per m^2 surface.

2.2.1.5 Artificial reproduction

Tench spawn in calm weather between the end of May and the middle of June, when the temperature of the water reaches 20°C. A female deposits about 300,000 eggs. The diameter of the egg is 0.8 - 1.0 mm; 100-120 sun-degrees are needed to hatch the eggs. The hatched larva is 4 or 5 mm long and digests its yolk reserve in 10 days. During active feeding its daily growth is 0.5 - 0.6 mm. It reproduces naturally. According to Schäperclaus (1961) tench will spawn:

(i) in a separate spawning pond 0.5 - 1.0 hectare in size in which 20 three-to four-summer-old females (300-400 g) and the same number of males are stocked;

(ii) when one or two females and the same number of males are stocked per hectare in a pond which is populated with one-summer-old carp;

(iii) in carp nursery ponds when three to six of each sex are stocked together with carp fingerlings. In this case the fish can be kept together during the following year too.

The tench spawning-pond should not be large, its bottom should be soft but not too muddy. It should also contain submerged aquatic plants (Myriophyllum, Ceratophyllum, Elodea, etc.).

No water should be drained during breeding time from the pond where tench fingerlings are; otherwise the fingerlings escape with the water. In these ponds there is no need for a water overflow.

In Hungary successful attempts were made in 1965 to breed tench artificially and rear them in incubators (Kovács, 1965). The one-summer-old tench is rather small (about 5 g in weight and about as long as a finger), so catching is difficult. Another difficulty is that some fingerlings are left in the shallower parts of the pond where water-fowl very soon eat them. The fingerlings may be gathered into the fish-bed only if the water is drained slowly by night. By day the water level should be constant. A pond two hectares in surface area takes three to four nights to drain (Rigger, in litt.)

Tench fingerlings can be fished from the fish-bed with the help of a fine-meshed net or can be collected in trap-boxes. In Hungary tench fingerlings are reared together with carp fingerlings in the same pond; they are caught together and not separated but, regardless of their number, are stocked together during the second summer. Selection and separation first takes place at the end of the second summer. The number of tench is controlled when stocked with two-summer-old carp.

2.2.1.6 Diseases

Tench do not get ascites as easily as carp, but Ergasilus sieboldi can cause considerable damage.

2.2.2 Silver crucian carp (Carassius auratus gibelio)

This fish grows slowly and is bony; it feeds mainly on plankton but also on the bottom on corn fodder given to carp. It was introduced into several countries (including Hungary) to replace carp stocks wiped out by ascites because it was said to be resistant to this disease. But experience in Hungary has shown that it does contract this disease. Males of the species are very rare in Europe, but deposited eggs can be fertilized by the sperm of crucian, tench and bleak. (This is apparently a type of parthenogenesis; proper hybridization does not take place). Silver crucian carp reproduce very easily and spawn virtually anywhere; they are easy to reproduce in fish ponds.

This fish is not very suitable for further propagation as it needs too much attention and when densely stocked it gets stunted.

2.2.3 Striped mullet (Mugil cephalus)

Experiments in breeding mullet in fish ponds have been carried out in the Soviet Union following the example of Israel (Zambriborshch, 1954). Striped mullet grow well in carp ponds and their oxygen consumption is less than that of carp. Babaian (1961) advocates rearing it separately.

2.3 Phytophagous species

Three species of phytophagous fish, Ctenopharyngodon idella the grass carp, Hypophthalmichthys molitrix the silver carp, and Aristichthys nobilis the bighead, were introduced into Europe from China and the River Amur and since then have become acclimatized in the European part of the Soviet Union. This has now (since 1963) become self-supporting for supplies of these fish. These species are also at present being acclimatized in Rumania and Hungary and attempts are being made to introduce them into Poland and Czechoslovakia.

2.3.1 Ctenopharyngodon idella

The advantages of rearing grass carp in fish ponds have been dealt with extensively by many authors, whose findings can be summarized as follows:

From their second summer on (when 60-100 g weight) grass carp feed mainly on aquatic plants (submerged, floating or emergent) and will also eat supplied fodder-plants such as lucerne, clover, etc. By cropping excess water plants, money can be saved on clearing water weeds, and they remove disintegrating substances from the water, thereby making it better for carp growth. As herbivores, their food chain is as short as possible, allowing the maximum production of fish flesh. Their excrement containing undigested plants, fertilizes the pond, increasing its productivity. It is also eaten by carp, which are given very useful bacteria flora by so doing. Grass carp grow rapidly, and are well liked by consumers. Artificial reproduction and rearing of fingerlings is now possible.

The disadvantages are: grass carp can spread parasites and diseases. They are very lively fish, very sensitive to loud noise and tend to jump out onto the bank; they grow only in warm weather and special care is needed for treatment and transport. In water below 14°C they do not eat (or eat very little). In Europe they mature when between four and seven years old, but reproduce naturally at only a few places (e.g. in South of Soviet Union and Japan).

Summing up, all authors agree that the grass carp is a valuable addition to the European fish farms.

2.3.1.1 Growth

The weights (g) achieved by grass carp in their first three years in different regions are as follows:-

Age group:	0	I	II
China	30-100	250-500	1500-3000
Moscow area	15- 25	200-250	800- 900
Turkmenia	20-420	360-850	1940-3100
Rumania	15- 25	200-850	800-1800
Hungary	50-150	550-1200	1500-4000

After the second summer we can count on one kilogram increase in weight per year. Six or seven year old specimens can weigh as much as 6 to 8 kilograms or more; in the river Amur one can find specimens weighing 20-30 kg. In the south of the Soviet Union they weighed 15-16 kg at five years of age (Babaian, in litt.) Their rate of growth in carp ponds is relatively slow during the first year, but during the second and mainly during the third summer they attain a considerable weight. Their growth depends on the food available.

2.3.1.2 Stocking

Grass carp have to be grown in a separate pond during the first summer. The following data refer to two and three-summer-old fishes (age groups I and II).

Information in the literature is only very general since in most places there is no large stock of these fish. If the eradication of vegetation is the primary aim, then 500-800 fish per hectare can be stocked in the pond (Tölg, in litt.) which is overgrown with weeds, followed by 200-500 fish per hectare if the two-summer-old grass carp failed to exterminate the water weeds. Three to four year old fish consume a vast amount of weeds and 80-150 or 30-50 of them respectively are to be stocked per hectare.

All vegetation have been found to be exterminated in Rumania by 160-240 fish/ha (3-4 summer-old) (Rumanian data, in litt.) Many more may be stocked in cases where they are fed on fodder-plants grown on dry land. So the number of stocked fish depends on:

(i) the age of fish;

(ii) the amount of water weeds;

(iii) how urgent the extermination of these weeds is; and

(iv) possible artificial feeding.

2.3.1.3 Feeding and care during breeding season

The optimum feeding temperature for grass carp is over 20°C; at 14°C they hardly eat anything; at 16°C they eat moderately. A specimen weighing 1 kg consumes daily 0.8-1.5 kg of green food. To attain 1 kg increase in weight they need 18-22 kg of green food (data from China). When feeding them on fodder-plants grown on dry land the chopped food-stuff is laid on a wooden frame, about 1 to 2 m^2, floating on the surface of the water. Only hard-stemmed land fodder can be chopped. These fish generally eat at night. Their intestinal canals are 2.1 times longer than their total lengths. In warm weather they eat as much as their own weight (Grozavu, 1962).

In shallow (0.8 - 1.5 m) carp ponds they exterminate water-weeds. Pénzes and Tölg (1964; *in litt.*) investigated the kinds of plants which were mostly consumed by specimens 400-800 g in weight. The different species of plants tested were each tied up in a bundle weighing 200 g and lowered to the bottom of a 3 m^3 aquarium. In two to eight hours the fish eagerly consumed the following plants: *Potamogeton natans*, *P. lucens*, *P. perfoliatus*, *Myriophylyum spicatum*, *Ceratophyllum demersum*, *Elodea canadensis*, *Cladophora* sp., *Spyrogyra* sp. In 8 to 24 hours they ate with good appetite the following plants: *Potamogeton crispus*, *P. pectinatus*, *Polygonum amphibium*, *Trapa natans*, *Hydrocharis morsus-ranae*, *Schoenoplectus tabernaemontani*, *Chara* sp. They ate well but left the stems of *Sium latifolium*, *Typha latifolia*, and *Phragmites communis*. In 24 to 48 hours they ate with moderate appetite, leaving the stems, *Typha augustifolia* and *Iris pseudacorus*. They hardly touched *Ranunculus trichophillus*.

Of land plants they were very eager to eat *Medicago sativa* and *Lartuca sativa*.

Fry gained 1 kg out of 50-80 kg wet duckweed (*Lemna*) consumed. The dry substance content of wet *Lemna* is about 5 percent (Szalay, 1965).

2.3.1.4 Fishing

Grass carp can be fished together with carp out of cold water without any difficulty. Their oxygen consumption does not differ considerably from that of carp. When fished out of warmer water they are very active, wriggling much and bruising themselves. For live transport the interior of the fish containers should be lined with fine mesh to prevent loss of a more serious kind. They should be transported in cold water (1-6°C).

2.3.1.5 Storage and overwintering

Grass carp inhabit warm waters but they can endure the European winter lasting for five to seven months in water at a temperature between 0 and 4°C without great loss. They endured the extremely cold winter in Hungary in the year 1963-64 without practically any loss (Tölg, *in litt.*) Carp ponds and storage basins can usually be used for their overwintering.

2.3.1.6 Artificial reproduction

The grass carp spawns on the sand beds of rivers in the country from where it was introduced. A sexually ripe specimen gives as much as 1.5 - 2 kg roe. In one cubic centimetre there are 900 eggs, their diameter is 1 - 1.2 mm and in water they become swollen. A swollen egg can be 5-6 mm in diameter and one cubic centimetre contains 12-13 of them. Swelling is at least 80 fold. The swollen eggs float under the surface of water (Vovk, 1957; Aliev, 1961; Verigin, 1961; Mirica, 1962).

At several places in the Soviet Union fingerlings are produced on a large scale by breeding them artificially. Eggs ripe for fertilization can be obtained by hypophysation. For this, carp and bream hypophysis (from the pituitary gland) is used in dried condition. The male fish are also hypophysed. Hypophysed fishes spawn in ponds or storage basins and could be stripped artificially. Grass carp mature at the following ages in various parts of Europe: Turkmenia three to four, Krasnodar five, the Ukraine eight or nine and Moscow area ten years.

Males reach maturity one year prior to females (Babaian, *in litt.*). They spawn at a temperature of 23-25°C. Hypophysation is also done at this temperature. The fish are hypophysed twice at 20-24 hours interval. Hypophysis is injected into the back muscle at the rate of one for each kg of body weight for females and two to three for males. The ova can be stripped 10-14 hours after the second injection, (Grozavu, 1962). The pulverized hypophysis is injected in a physiological salt solution. The Gelbinsky method using acetone is suggested for the preparation of hypophysis.

Fertilization is very simple, it can be done using the dry method. For incubation 30-50 litre Zuger glasses are used. An 8 litre glass can contain 50,000-70,000 eggs. Soin (1959) suggests the use of a cylindrical revolving incubator.

At a temperature of 25°C incubation takes 30-32 hours, at 28°C it takes 24 hours; during this period the eggs grow and the larvae hatch. The hatched larvae are washed out of the glasses and are reared in boxes made of perlon sieve-sheets with 0.15 - 0.20 mm (150-200) hole size. The larvae are able to eat two or three days later.

From the day of fertilization it takes only five days until they begin to eat at a temperature of 23-25°C. The young fish that are able to eat are stocked into nursery ponds. If this stocking takes place sooner than it should, a considerable number of them die. But if we wait until they attain the ability to eat, as many as 50 percent can survive.

First they feed on small crustaceans (*Cyclops*, *Diaptomus*, *Daphnia*, etc.). But soon they begin to eat algae and *Lemna* (Szalay, 1964). *Lemna*, produced in separate ponds, has proved to be a highly satisfactory nourishment for fingerlings. Rearing one-summer-old grass carp (age group 0) together with carp does not give good results; so they are reared for the first summer (in two periods) in separate small ponds. The first period lasts until they reach the weight of 5 g, and they are fed on zooplankton, algae and plants containing little fibre (*Lemna*). In the second period they are reared mainly on vegetable food (*Lemna*, lucerne, clover) but animal proteins must be present in the diet. In Hungary a special artificial food-mixture with 30 percent protein content is prepared for young carp. (The food mixture for young trout is likely to be similarly effective). Feeding them on artificial foods and vegetable feeds 40-50,000 fish can be reared per hectare. In order to exterminate harmful insects it is useful to have 200-300 three-summer-old carp per hectare, (Szalay, 1965).

Three- to ten-day old fish, then 5 to 6 mm long can be transported over very long distances. As many as 50,000 fish can be transported in a polythene bag containing 20 litre water and 20-25 litre oxygen (Tölg, *in litt.*). Rearing methods applied in China (for all the three herbivorous species) were described by Ni Da Su (1962).

2.3.1.7 Parasites and diseases

With the fishes introduced from China new types of parasites were also brought in, such as the tapeworm *Botriocephalus gowkongensis* which can spread to carp and other species, the *Myxobolus* (fluke-worm), *Dactylogyrus lamellatus* and, *Dactylogyrus sp.* These parasites have not done noticeable damage to our native fish fauna. Their further spreading can be prevented by hatching "sterile" fingerlings in hatcheries. According to some data from Rumania grass carp do not get infected by ascites but Hungarian investigators maintain that they do get this disease.

2.3.1.8 Yield increase

Grass carp reared together with carp add considerably to the yield from ponds. Schäperclaus (1963) mentions yields of 50 kg/ha, but in Rumania they have produced as much as 500 kg/ha (personal information). Stocking 300 grass carp/ha gave 120 kg, 150/ha gave 84-171 kg, and 100/ha gave 112-128 kg increase in fish yield (Nicolau, 1962). Data from the Soviet Union show that the yield with this species can be increased by 150-200 percent (Babaiah, 1962).

2.3.2 Hypophthalmichthys molitrix

Hypophthalmichthys molitrix was introduced into Europe together with Ctenopharyngodon idella. Its nutrition differs from that of grass carp because it feeds primarily on planktonic algae sifted through a complicated branchial filter (Zambriborch, 1954). This species proves to be highly useful in consuming blue-green algae in fertilized and heavily stocked carp ponds. It also feeds on filamentous algae. Thus it uses in a direct way food-stuffs in our ponds which are otherwise hardly used, or used only indirectly, and by eating the so-called harmful algae it contributes to carp production.

The advantages and disadvantages of this species are said to be similar to those of grass carp. When young the fingerlings also feed on zooplankton.

2.3.2.1 Growth

Growth is fairly slow during the first year, but from the second year becomes faster, the rate depending on the food-stuff available. The intestines are 5.3 - 7.9 times longer than the body length (Grozavu, 1962).

The increase in weight (g) in different areas is (according to Scheer, 1964 and Hungarian data) as follows:-

Age group:	0	I	II
China	12-22	500-1500	2000-3000
Moscow area	3-5	120- 800	417-1205
Turkmenia	21-55	1100-1850	3290-4250
Rumania	164	2030	2500-4000
Hungary	57-66		

In Rumania the stocked two-summer-old fish increased 1,700 g in weight during the third summer. Specimens which reached maturity weigh as much as 6 to 8 kg (age six to nine years).

2.3.2.2. Stocking rate

Second and third year fish in Rumania stocked 250-500 ha gave 250-500 kg increase in fish crop. Forty-five third-year fish yielded 120 kg increase per hectare (Nicolau, 1962).

The stocking rate should be determined for each pond by considering the amount of algae in the pond and the amount of manure used.

2.3.2.3 Fishing and transport

This species is much more sensitive than grass carp, its gills get soon filled with mud and must be washed out in clean water. They are quieter in cool water.

More care is required in their transport than in the case of grass carp. They are very uneasy when transported and get bruised and die very easily. Transport containers should be lined with fine mesh in order to avoid heavy losses.

They can only be transported in water at a temperature of 1°-6°C, (Akhmerov, 1955). Storage and overwintering in this species are similar to those of grass carp.

2.3.2.4 Artifical reproduction

Spawning conditions are very similar to those of grass carp and their artificial reproduction is carried out in exactly the same way. They are reared in nursery ponds when one summer old (age Group 0). These ponds should be well fertilized and small

(1 to 5 ha). No special methods have been developed for their feeding. They are said to be resistant to ascites (Rumanian and Hungarian observations).

2.3.3 Aristichthys nobilis

This species is not native to the River Amur, but lives in other rivers and ponds of China. It feeds primarily on zooplankton, algae and floating detritus. It grows rapidly but to some extent it competes with carp for food.

2.3.3.1 Growth

This species grows faster than any of the above mentioned species especially after the third summer. In Rumania three-summer-old fish weighed 4,500-7,500 g, (Nicolau, 1962). Its intestines are 3.2 - 5 times longer than the body length.

2.3.3.2 Artificial reproduction

The breeding of this species is similar to that of the above-mentioned Chinese species. The hybridisation of Hypophthalmichthys molitrix and Aristichthys nobilis has proved to be successful (Vinogradov and Erochina, 1964). For rearing young fish smaller, separate ponds should be used with ample plankton.

2.3.4 Tilapia sp.

Initial experiments with Tilapia in Europe appear to have yielded some results only in the south of France, but no published data are available.

2.4 Other animals

The yield of carp ponds can be increased in other ways. In Europe breeding nutria (Myocaster coypus) in carp ponds produced a considerable increase in yield. Nutria increases fish production by destroying aquatic plants and by fertilizing the ponds with its excrement.

In several countries (Czechoslovakia, Hungary, East Germany) duck rearing on fish ponds has spread, especially since the second world war. Properly treated 10 day-old ducklings can be reared in 50-52 days, and they weigh as much as 2.2-2.5 kg if food is continually provided for them. Their excrement increases the fish crop. The food dropped by ducks is not wasted because the fish utilise it. Three to four hundred ducks yearly can be reared per hectare in two to three successive groups.

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VIII/R-4

NOUVEAUX POISSONS ET NOUVEAUX SYSTEMES POUR LA PISCICULTURE EN AFRIQUE

par

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Résumé

Le document constitue un essai de synthèse des travaux effectués sur les nouveaux poissons et nouveaux systèmes de pisciculture en Afrique. Un système de pisciculture est défini comme l'utilisation d'une méthode de pisciculture dans des conditions écologiques et socio-économiques déterminées. Les nouveaux poissons employés en pisciculture en Afrique sont d'abord les différents tilapia sauvages macrophytophages et microphages auxquels viennent s'ajouter depuis peu des hybrides obtenus par des croisements donnant en totalité des mâles. L'Heterotis niloticus est élevé dans quelques pays. On cite également les prédateurs Hemichromis fasciatus et Lates niloticus ainsi que les Mugil et la crevette Penaeus duorarum, encore sous expérience. Parmi les poissons exotiques, la carpe, dont l'utilisation en Afrique a donné lieu à de nombreuses controverses, connaît un regain d'intérêt. Les systèmes de pisciculture se sont perfectionnés depuis la pisciculture communautaire ou familiale préconisée entre 1953 et 1958. La pisciculture artisanale à but commercial, plus ou moins intégrée dans une exploitation agricole, constitue un pas en avant tandis qu'actuellement se dégage une tendance à une pisciculture utilisant des poissons de valeur (tilapia hybrides, Heterotis, carpes) dont les alevins sont acquis par le pisciculteur auprès d'une station spécialisée. Il semble que cet élevage des poissons améliorés fournis par des stations, en étangs intégrés de préférence dans un contexte agricole, soit la voie d'avenir. Ce système suppose une liaison permanente des services de vulgarisation avec les producteurs; une telle liaison est hautement désirable. Le système n'est évidemment réalisable que si les services disposent de moyens d'action suffisants. Pour leur permettre un travail efficace, il sera nécessaire d'éviter une trop grande dispersion et donc de sélectionner pour le développement de la pisciculture les lieux où le milieu physique et socio-économique lui est spécialement favorable.

NEW FISHES AND NEW SYSTEMS OF FISH CULTURE IN AFRICA

Summary

This paper collates work on new fishes and new systems of fish culture in Africa. A fish culture system is defined as a method applicable under specific ecological and socio-economic conditions. The new fishes employed in African fish culture comprise, first, several wild macrophytophagous and microphagous tilapia and, more recently, hybrids obtained by crossings which give all males. Heterotis niloticus is also raised in some countries and mention is made of the predators Hemichromis fasciatus and Lates niloticus, as well as Mugilidae and Penaeus duorarum with which trials are still in progress. As regards the introduction of exotic fish, there is a revival of interest in carp, the use of which in Africa has given rise to much controversy. Fish culture systems have been developed and improved upon, starting with community or family fish ponds that were much in favour between 1953 and 1958. Small-scale fish ponds for commercial purposes, more or less an integral part of farms, are a step forward; however, there is a tendency at present to grow good quality fish in ponds (tilapia hybrids, Heterotis, carp), the fry being procured by the fish-culturist from a specialized station. It seems that raising selected fish supplied by such stations, in ponds which are preferably an integral part of an agricultural complex, is the future road. Such a system implies the permanent liaison of agricultural extension services with producers, something highly desirable. This system can only be put into effect if the services have adequate facilities. In order to enable them to carry out effective work they must not be too widely dispersed; especially favourable sites from the physical and socio-economic standpoints have to be selected for such stations in order to promote fish culture.

NUEVOS PECES Y NUEVOS SISTEMAS PARA LA PISCICULTURA EN AFRICA

Extracto

El documento constituye un ensayo analítico de los trabajos efectuados sobre los nuevos peces y nuevos sistemas de piscicultura en Africa. Un sistema de piscicultura viene definido como la aplicación de un método de piscicultura en condiciones ecológicas y socioeconómicas determinadas. Los nuevos peces empleados en piscicultura en Africa son en primer lugar las diferentes tilapia silvestres macrofitófagas y micrófagas a las cuales se añaden desde hace poco los híbridos obtenidos por cruzamiento que dan machos en su totalidad. Heterotis niloticus es cultivado en varios países. Igualmente se cita a los predadores Hemichromis fasciatus y Lates niloticus, así como a los Mugil y al camarón Penaeus duorarum, que todavía están bajo experimentación. Entre los peces exóticos, registra un aumento de interés la carpa cuya utilización en Africa ha dado origen a numerosas controversias. Los sistemas de piscicultura se han perfeccionado desde la piscicultura comunitaria o familiar preconizada entre 1953 y 1958. La piscicultura artesanal con fines comerciales más o menos integrada en una explotación agrícola, constituye un paso adelante, mientras que, actualmente, se observa una tendencia hacia una piscicultura que utilice peces de valor (híbridos de tilapia, Heterotis, carpas) cuyos alevines adquiere el piscicultor en una estación especializada. Parece que esta cría de peces mejorados proporcionados por las estaciones, en estanques integrados preferentemente en un conjunto agrícola, sean la vía del porvenir. Este sistema supone un enlace permanente de los servicios de divulgación con los productores; este enlace es muy deseable. El sistema, evidentemente, no es realizable si los servicios no disponen de medios de acción suficientes. Para permitirles un trabajo eficaz, será necesario evitar una excesiva dispersión y, por tanto, seleccionar para el desarrollo de la piscicultura, los lugares en que el medio físico y socioeconómico sean especialmente favorables para ella.

1 INTRODUCTION

Le présent document constitue un essai de synthèse des informations parvenues à la connaissance de ses rédacteurs sur les "nouveaux poissons et les nouveaux systèmes de pisciculture en Afrique". S'agissant d'une région où la pisciculture était pratiquement inconnue il y a 20 ans (à part quelques essais de repeuplement dans les lacs et cours d'eau en Afrique du Nord, en Afrique orientale, en Afrique du Sud et à Madagascar), on peut estimer que le qualificatif "nouveau" s'applique à l'ensemble des travaux effectués sur la pisciculture alimentaire en Afrique. Pour cette raison, la synthèse présentée ici retiendra donc cet ensemble.

1.1 Afin de faciliter la compréhension du document et de préciser la place qu'il occupe dans la série des travaux de même nature, il convient d'apporter quelques définitions:

Mous devons d'abord préciser ce que nous entendons par: système de pisciculture. Nous n'allons pouvoir le faire qu'après avoir défini au préalable deux autres termes: technique de pisciculture et méthode de pisciculture.

Une "technique de pisciculture" est un procédé déterminé applicable à une opération de pisciculture. La fécondation artificielle des poissons, leur alimentation artificielle, le chaulage des étangs, sont des techniques de pisciculture.

Une "méthode de pisciculture" est la combinaison d'un ensemble de techniques de pisciculture. L'élevage de la Carpe commune par classes d'âges séparées, l'élevage intensif des Tilapia par classes d'âges mélangées, sont des méthodes de pisculture.

Un "système de pisciculture" est l'utilisation d'une "méthode de pisciculture" dans des conditions écologiques et socio-économiques déterminées. L'élevage du Chanos chanos dans les "Tambaks" d'Indonésie constitue un système de pisciculture.

1.2 Les retenues d'eau artificielles créées dans des buts divers (besoins en eau des humains et du bétail, irrigation, conservation des sols, production d'énergie électrique, etc....) qui sont de plus en plus nombreuses en Afrique et qui sont aménagées en vue d'une production de poissons, ne peuvent, à notre avis, être assimilées à des étangs de pisciculture que si elles ne constituent plus un écosystème libre et si les interventions qui s'y exercent sont telles que l'on puisse les assimiler à un terrain de culture. Nous considérerons donc que seules appartiennent à un système de pisciculture celles faisant l'objet de mises en charge et de vidanges périodiques à intervalles plus ou moins réguliers.

1.3 Comme les systèmes de pisciculture se définissent, au moins en partie, à raison de l'espèce de poisson utilisée, on présentera d'abord les nouveaux poissons de pisciculture africains, puis les systèmes qui les mettent en cause.

2 POISSONS DE PISCICULTURE

Nous ne mentionnerons ici que les poissons faisant effectivement à l'heure actuelle et à des fins alimentaires, l'objet d'élevages, soit dans la pratique, soit à titre expérimental. Nous ne parlerons pas de ceux qui, après avoir été depuis 1945 l'objet d'essais plus ou moins poussés, ont été abandonnés et qui ne sont donc pas actuellement des poissons de pisciculture africains. On pourra d'ailleurs en trouver la liste dans un travail de l'un d'entre nous (Bard, 1962).

2.1 Poissons africains

2.1.1 Tilapia (Cichlidae)

Il faut citer d'abord T. melanopleura et T. zillii, expèces macrophytophages, à résilience particulièrement élevée et ne pratiquant pas l'incubation buccale. Leur régime alimentaire les rend spécialement intéressants, car leur alimentation artificielle à l'aide de feuilles diverses (manioc, patates, colocase, etc...) est facile dans beaucoup de régions d'Afrique. En contrepartie, leur résilience élevée entraîne une surpolulation en jeunes sujets particulièrement rapide dans les élevages.

Il faut noter que des confusions ont été faites assez fréquemment dans la dénomination de ces deux espèces. Elles ne pourront être tout à fait éclaircies que lorsque une révision systématique des espèces du genre Tilapia actuellement en cours sera achevée.

Les autres espèces de *Tilapia* utilisées en pisciculture sont: *T. macrochir* *T. andersonii*, *T. nilotica*, *T. mossambica*, *T. nigra*, *T. esculenta*, *T. galilea*, *T. multifasciata*, *T. variabilis*, *T. leucosticta*.

Ce sont des espèces microphages ou omnivores à résilience, en général, moins élevée que les espèces macrophythophages et qui pratiquent l'incubation buccale. Les quatre dernières ne donnent que des résultats médiocres. *T. nigra* n'est guère utilisé qu'au Kenya. *T. macrochir* et *T. nilotica* sont largement employés dans l'Afrique de l'Ouest où T. nilotica semble cependant avoir une meilleure croissance.

2.1.2 Tilapia hybrides

Le croisement de *T. mossambica* mâle avec *T. nilotica* femelle réalisé en Uganda, donne des hybrides tous mâles (Pruginin et Kanyike, 1965)

Ces hybrides commencent à être utilisés pour la pisciculture dans ce pays car ils permettent des élevages monosexes dont la réalisation, avec les espèces sauvages de Tilapia, peut être difficile dans la pratique courante.

Des hybrides également tous mâles ont été obtenus en Uganda par le croisement de *T. aurea* mâle avec *T. nilotica* femelle et en Côte d'Ivoire par le croisement de *T. macrochir* mâle avec *T. nilotica* femelle. Leur utilisation pratique n'a pas encore commencé; la production du second en quantités importantes n'a pas pu jusqu'ici être réalisée de façon satisfaisante.

2.1.3 *Heterotis niloticus* (Osteoglossidae)

Les possibilités d'utilisation d'*Heterotis niloticus* comme poisson de pisciculture ont été signalées en 1956 par Daget et d'Aubenton. Il a fait l'objet d'études diverses qui ont permis de préciser ses conditions de reproduction et de croissance en étang (Tillon 1959; Bard 1960; Olaniyan et Zwilling 1963; Reizer 1964). Avec une bonne alimentation artificielle, il peut donner des sujets de 1 kg en un an avec un rendement de 2 tonnes à l'hectare. Son élevage est pratiqué au Cameroun et en République Centrafricaine. Bien que dans l'ensemble, sa chair ne soit pas d'aussi bonne qualité que celle des tilapia, sa rapidité de croissance et les tailles élevées qu'il atteint lui valent une grande faveur auprès des pisciculteurs. La production d'alevins en quantités importantes dans les stations de pisciculture pose encore quelques problèmes.

2.1.4 *Hemichromis fasciatus* (Cichlidae)

Il est assez peu utilisé et uniquement comme poisson prédateur pour contrôler la reproduction excessive des tilapia. Ses conditions d'emploi ont été étudiées au Congo Léopoldville (Gruber et Mathieu, 1959), en Côte d'Ivoire (Lessent, 1959) et au Cameroun (Bard, 196)).

2.1.5 *Lates niloticus* (Centropomidae)

Son utilisation comme poisson prédateur pour contrôler la reproduction des Tilapia en est encore au stade expérimental. Elle a été étudiée au Nigeria entre 1954 et 1961 et l'on est arrivé facilement à le faire se reproduire en étang (Federal Fisheries

Service, Lagos, 1963). Elle fait actuellement l'objet d'expérimentations en Uganda où par contre sa reproduction en station de pisciculture semble soulever des difficultés (Pruginin et Kanyike, 1965).

2.1.6 Mulets (Mugilidae)

Des essais d'élevage de diverses espèces de mulets (Mugil grandisquamis, M. falcipinnis et M. capito) ont été entrepris dans le Delta du Niger (FAO/UN, 1965) et en Egypte (El Bolock et Labib, 1965).

2.1.7 A cette liste de poissons, il faut ajouter un crustacé : Penaeus duorarum

Les essais de pisciculture dans le Delta du Niger ont porté également sur cette crevette abondante dans les eaux naturelles.

2.2 Poissons exotiques

2.2.1 Cyprinus carpio (Cyprinidae)

La carpe commune a été introduite depuis assez longtemps à Madagascar et dans diverses parties d'Afrique (Afrique du Sud, Rhodésie du Sud, Egypte, Maroc), mais elle n'y a pas fait l'objet de véritables élevages en étangs jusqu'à une date récente. Son introduction éventuelle dans divers pays de la zone intertropicale africaine en vue de son utilisation comme poisson de pisciculture a donné lieu, de 1949 à 1960, à de nombreuses controverses (De Bont, 1950; Maar, 1960; Rhodes, 1963). Elle a cependant été introduite au Nigéria en 1954 et en Uganda en 1957. En dehors de Madagascar où son élevage a déja pris une certaine extension, on commence seulement à l'utiliser dans la pratique en Uganda. Elle fait l'objet d'expériences en Egypte. La production ,pour les besoins des pisciculteurs d'alevins en quantités importantes dans des stations spécialisées n'est pas encore entièrement au point.

3 SYSTEMES DE PISCICULTURE

3.1 Description des méthodes

Le classement et la description des systèmes de pisciculture nécessitent évidemment, au préalable, la description des méthodes qu'ils utilisent. C'est ce que nous allons faire très brièvement. On peut en distinguer en théorie quatre:

a) Méthode d'élevage de tilapia par classes d'âge mélangées-. Elle a été élaborée au Congo Belge (De Bont, 1952) et reprise ensuite dans divers pays. L'alevinage et la production se font dans le même étang qui est chargé avec des poissons de tous âges. La mise en charge est très forte. Au bout de trois ou quatre mois, la charge de l'étang devient voisine de sa capacité et on la maintient à ce niveau par des pêches intermédiaires. Après huit à douze mois, l'étang est vidé et tout le poisson récolté. Au moment de la vidange, on prélève sur la récolte la quantité de poissons nécessaire pour une nouvelle mise en charge.

L'expérience a montré que, dans la pratique, cette méthode peut fournir, si les poissons sont bien alimentés artificiellement, des productions totales très élevées (plusieurs tonnes par hectare et par an), mais la reproduction précoce et répétée des tilapia (surtout dans les régions où elle n'est pas interrompue par une saison froide) amène rapidement une surpopulation en jeunes sujets et l'on ne récolte pratiquement qu'une proportion très faible de gros poissons.

b) Méthode d'élevage de tilapia par classes d'âge séparées.- Elle a été conçue pour essayer de remédier aux inconvénients de la méthode précédente. L'alevinage et la production se font toujours dans le même étang, mais celui-ci est chargé avec des alevins de même âge que l'on y élève jusqu'à ce qu'ils se soient reproduits une fois. A la vidange

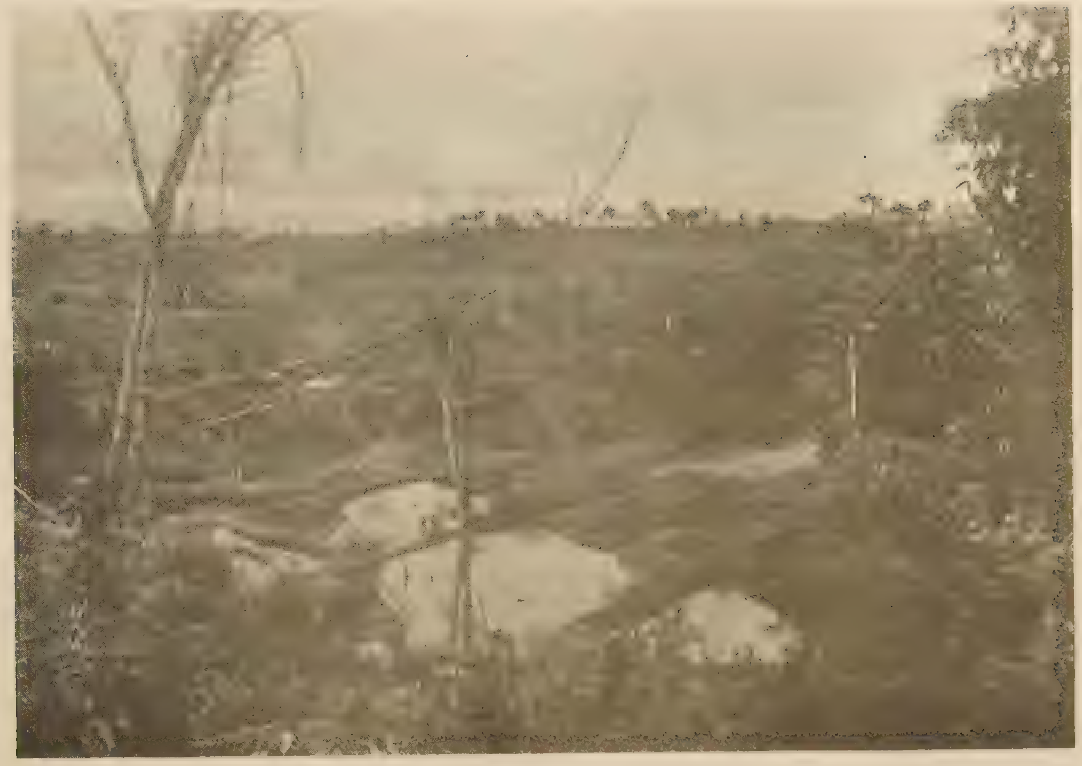

Fig.1 Etangs de pisciculture familiale de subsistance (Congo-Brazzaville)

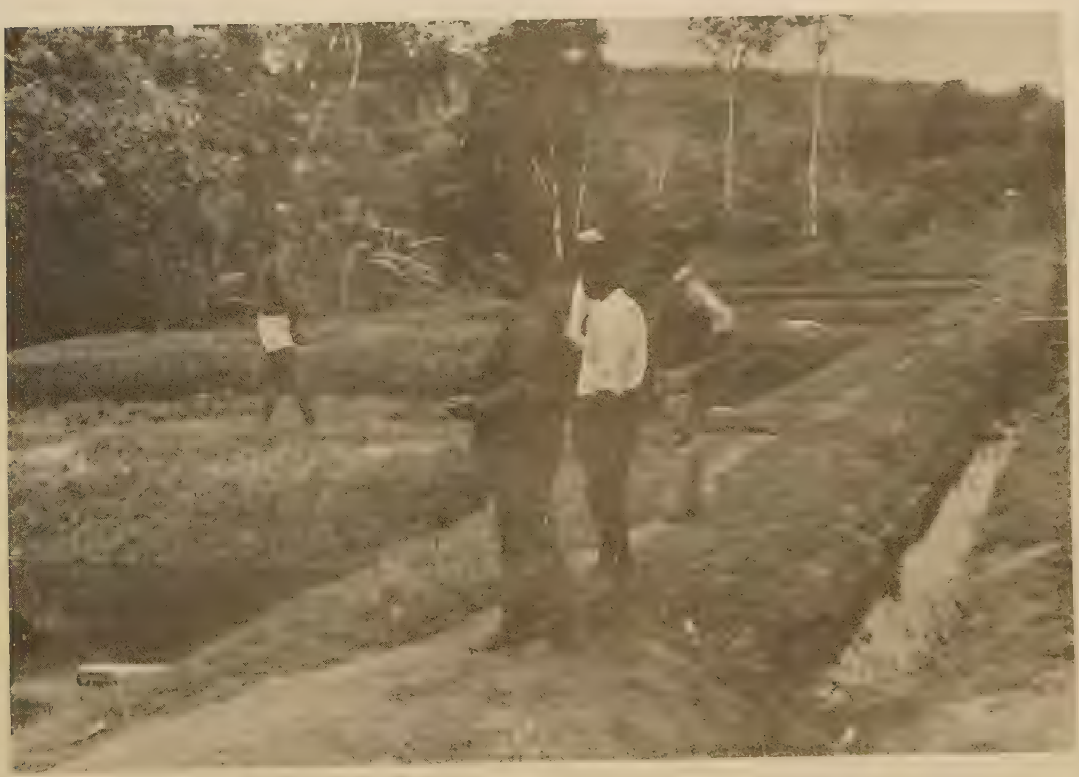

Fig.2 Etangs de pisciculture artisanale (Congo-Brazzaville)

de l'étang, on recueille les poissons adultes pour la consommation. Leur poids individuel reste malheureusement relativement faible (60 à 100 g). Les alevins servent pour une nouvelle mise en charge. Il a été démontré (Charpy, 1958) que cette méthode ne peut fournir qu'une production pondérale nettement plus faible que la précédente.

Il faut noter qu'il est relativement rare de rencontrer les deux méthodes d'élevage des tilapia par classes d'âge mélangées et par classes d'âge séparées pratiquées à l'état pur. Elles sont presque toujours plus ou moins combinées ou mélangées. Très souvent, un élevage commence avec les caractéristiques de la seconde pour se continuer avec celles de la première. C'est pourquoi, dans la suite de cet exposé, nous réunirons ces deux méthodes sous la dénomination de : Méthode d'élevage des tilapia avec alevinage et production mêlés dans un seul étang.

c) Méthode d'élevage de tilapia associés avec un prédateur. Elle consiste à introduire un prédateur pour contrôler les populations de tilapia dans les élevages conduits suivant l'une des deux méthodes précédentes. Les prédateurs actuellement utilisés sont Hemichromis fasciatus et Lates niloticus.

d) Méthode d'élevage equienne d'espèces diverses.- L'alevinage et la production sont deux opérations nettement séparées. Elles s'effectuent dans des étangs différents en ce qui concerne la Carpe, l'Heterotis niloticus, les tilapia hybrides monosexes. L'opération "production" existe seule avec des espèces telles que les mulets dont les alevins sont récoltés dans les eaux naturelles. La production est faite à partir d'alevins sensiblement de même âge et fournit des poissons à peu près calibrés.

Si les quatre méthodes précédentes ont en théorie des caractéristiques bien différentes, elles interfèrent souvent entre elles dans la pratique africaine. Il est des cas où, par exemple, un élevage équienne d'Heterotis niloticus ou de Carpe se fait en mélange avec un élevage de Tilapia par classes d'âge mélangées.

3.2 Systèmes d'élevage des tilapia avec alevinage et production mêlés

3.2.1 Pisciculture communautaire de subsistance

C'est un système qui a été pratiqué le premier en Afrique dans les débuts de la pisciculture. Il utilise des étangs d'assez grandes dimensions (dix ares à quelques hectares) construits en général sur des crédits publics et munis de dispositifs en matériaux durs pour la vidange. Leur exploitation est assurée par la communauté africaine (village, école) qui affecte leur production à sa subsistance.

Les conditions d'exploitation sont généralement médiocres; les mises en charge, les pêches intermédiaires et les vidanges sont souvent faites plus ou moins au hasard. La plupart du temps, personne ne se préoccupe de distribuer une alimentation artificielle aux poissons. La production est, de ce fait, généralement faible: quelques centaines de kilogs à l'hectare.

Ce système de pisciculture n'a connu qu'un développement extrêmement limité car, compte tenu de ses résultats fréquemment peu encourageants, les services responsables ont très vite porté leurs efforts vers la vulgarisation de la pisciculture familiale de subsistance.

3.2.2 Pisciculture familiale de subsistance

Elle est conçue de façon à ce que le paysan puisse produire dans un étang lui appartenant, construit et exploité par lui, sans dépenses en argent et grâce à un travail relativement faible, les protéines dont il a besoin pour l'alimentation de sa famille.

Elle se pratique en étangs de très faibles dimensions (parfois moins d'un are et au maximum quelques ares) qui demandent une alimentation en eau régulière et relativement constante. Elle exige donc la présence de sources ou de petits cours d'eau permanents. Les étangs sont souvent mal aménagés et mal entretenus. Les dispositifs d'alimentation en eau et de vidange sont fréquemment rudimentaires et il n'est généralement pas possible de vidanger complètement par gravité. On élève une ou plusieurs espèces de tilapia La mise en charge, constituée le plus souvent par ce qui reste dans l'étang après une vidange incomplète, est variable et imprécise.

L'alimentation artificielle des poissons fait appel à des sous-produits de l'agriculture locale, en principe gratuits (feuilles de manioc, de colocase, graines de coton, drèches de bière, etc...). Elle devrait être intensive pour que la faible superficie des étangs soit compensée par une production unitaire élevée. Elle n'est ordinairement ni très régulière ni très abondante.

La vidange des étangs se fait à intervalles irréguliers, parfois très longs: deux ou trois ans. On pratique, en général, des pêches intermédiaires: le plus souvent à la ligne.

La production obtenue est extrêmement variable. Elle peut être presque nulle ou atteindre 20 à 25 kgs à l'are et par an. Elle est constituée par une très grande majorité de poissons de petite taille.

Ce système de pisciculture a connu en Afrique intertropicale un développement spectaculaire entre 1953 et 1958. Des dizaines de milliers d'étangs ont été construits dans les zones qui paraissaient offrir un milieu physique favorable, des disponibilités en eau suffisantes et dans lesquelles les services gouvernementaux responsables ont exercé une propagande active, telles que les régions du Kwilu et du Kasai au Congo Léopoldville, le Sud du Congo Brazzaville, l'Ouest du Cameroun, l'Ouest de la République Centrafricaine, la région de Nyanza au Kenya, celles de Buganda et Kigezi en Uganda, le Centre et l'Est de Madagascar.

Depuis 1958, on a enregistré une régression importante de ce systéme pour diverses raisons dont nous parlerons plus loin (voir section 4). Parmi les pisciculteurs qui l'utilisaient, beaucoup ont abandonné leurs étangs, d'autres ont persévéré dans la mesure où ils étaient aidés et soutenus par des services d'encadrement efficaces, certains se sont orientés vers la pratique d'un autre système de pisciculture.

3.2.3 Pisciculture artisanale

Dans ce système, la production n'a qu'un rôle accessoire de subsistance, elle est destinée à être livrée au commerce en totalité ou en partie ou bien à satisfaire les besoins alimentaires d'une exploitation agricole dépassant le cadre familial.

Cette pisciculture utilise généralement des étangs plus grands que la pisciculture familiale. De ce fait, pour leur construction, il arrive que le propriétaire soit amené à employer de la main-d'oeuvre extérieure ou des engins mécaniques et, par conséquent, à faire un investissement en argent. Ce système a parfois comme point de départ une pisciculture familiale située dans des conditions favorables au voisinage d'un centre de commercialisation et dont l'étang ou les étangs ont été améliorés ou agrandis.

On élève une ou plusieurs espèces de tilapia. Les mises en charge, les vidanges et éventuellement les pêches intermédiaires, sont réalisées avec plus de soin et de régularité qu'en pisciculture familiale. Il en est de même pour l'alimentation artificielle des poissons. Les productions obtenues sont en conséquence plus élevées.

3.2.4 Pisciculture intégrée à une exploitation agricole

L'intégration réelle dans l'économie de la ferme africaine de la pisciculture considérée comme une culture parmi les autres cultures constitue un des buts poursuivis par la plupart des responsables de son développement. Certaines piscicultures familiales ou artisanales manifestent une orientation nette dans cette voie: cultures sur les digues, rouissage du manioc dans les étangs, etc...

Mais le système paraît commencer à s'établir en Zambie sous forme de petites fermes qui combinent la production des légumes, des canards et du poisson (Mortimer, Ruth et Muluwa, 1963). Quelques associations d'élevage du porc avec la pisciculture existent au Cameroun.

On pratique dans les étangs l'élevage de plusieurs espèces de tilapia par classes d'âge mélangées. Les poissons sont nourris de détritus de légumes, d'herbe et de fumier de canards ou de porcs. A chaque vidange, la vase des étangs est enlevée et utilisée pour fertiliser le potager.

L'établissement de fermes de ce genre est évidemment particulièrement indiqué à proximité immédiate de centres urbains.

3.2.5 Pisciculture dans des retenues d'eau créees dans des buts divers

Contrairement aux systèmes de pisciculture précédents qui exigent un climat relativement humide et des ressources en eau permanentes, celui-ci concerne les régions à longue saison sèche où l'on est amené à créer des réserves d'eau pour des buts divers (besoins domestiques, conservation des sols, irrigation, etc....). Certaines réserves, soit qu'elles puissent être vidangées à peu près régulièrement, soit qu'elles s'assèchent naturellement, permettent la réalisation d'une pisciculture dont l'extension reste limitée. Il est possible d'indiquer que des essais de développement de ce système ont été entrepris en Kabylie (Algérie) en 1961. L'irrigation des cultures nécessitent l'établissement en tête de vallée, de lacs collinaires d'une dizaine d'hectares qui s'assèchent d'octobre à janvier. On y stocke en janvier des T. mossambica. Ils sont récoltés au moment de l'assèchement. La mise en charge est fournie grâce à un petit étang de quelques ares, suffisamment profond pour garder l'eau toute l'année, où un stock de tilapia est entretenu. La gestion est assurée par la Coopérative groupant les agriculteurs de la vallée.

3.3 Systèmes utilisant l'élevage des Tilapia associés à un prédateur

3.3.1 Pisciculture artisanale

Ce système ne diffère pratiquement de la pisciculture artisanale décrite plus haut (section 3.2.3) que par l'adjonction d'un prédateur au stock de tilapia. Son utilisation n'est pas courante. Comme les alevins de tilapia sont détruits par le prédateur, il faut prévoir une fourniture d'alevins provenant d'une source extérieure (généralement une station). Ce système est signalé au Cameroun (Bard, 1960).

3.4 Systèmes utilisant l'élevage equienne d'espèces diverses

3.4.1 Pisciculture artisanale dans laquelle l'éleveur ne pratique pas l'alevinage

Dans ce système, le pisciculteur limite son activité à la production de poissons de consommation à partir d'alevins qu'il se procure dans des établissements d'alevinage spécialisés, généralement gouvernementaux, ou dans les eaux naturelles.

Ce système commence à prendre une certaine extension avec la carpe à Madagascar et sa vulgarisation a débuté récemment en Uganda avec la carpe (et des tilapia hybrides monosexes).

A Madagascar, il est en général pratiqué par des fermiers évolués ayant commencé leur activité de pisciculteurs en élevant des tilapia par classes d'âge mélangées. Ils n'ont pas été satisfaits des résultats et sont disposés à faire des efforts pour en obtenir de meilleurs avec la carpe. Ils ont agrandi leurs étangs, en ont amélioré l'aménagement et nourrissent mieux les poissons.

Des essais de pisciculture en eau saumâtre de mulets et de crevettes avec récolte dans les eaux naturelles des alevins et larves nécessaires aux mises en charge, ont été entrepris récemment dans le Delta du Niger (FAO/UN, 1965).

3.4.2 Pisciculture industrielle dans laquelle l'éleveur pratique à la fois l'alevinage et la production mais dans des étangs séparés.

Les tentatives faites pour l'utilisation d'un tel système avec les Tilapia ont échoué. Ni leur biologie, ni les possibilités des pisciculteurs ne s'y prêtent.

On a essayé au Nigeria, de 1954 à 1961, à la ferme de pisciculture de Panyam, sur le plateau de Jos, un élevage de carpe à caractère industriel. Les résultats ont été satisfaisants sur le plan technique (Federal Fisheries Service, 1963), mais le système ne paraît pas économiquement viable.

Les conditions d'un élevage de carpe à caractère industriel ont également été étudiées récemment en Egypte à la station de pisciculture expérimentale de Serow (El Bolock et Labib, 1965).

4 DISCUSSION

Au cours des quinze années qui viennent de s'écouler, l'histoire de la pisciculture envisagée à des fins alimentaires, tout spécialement dans le but de contribuer à combler le déficit en protéines animales dont souffrent les populations africaines et malgaches, peut être schématisée de façon assez simple.

Une pisciculture familiale de subsistance, basée sur une méthode plus facile d'élevage de diverses espèces de tilapia a connu un développement rapide là ou un effort de propagande a été entrepris en sa faveur. Elle n'a pas donné tous les espoirs qui avaient été mis en elle et a subi alors une régression importante. Les recherches entreprises et l'expérience acquise ont permis de s'orienter vers d'autres systèmes et d'autres poissons de pisciculture.

La raison essentielle pour laquelle la pisciculture familiale de subsistance n'a pas tenu toutes ses promesses est que la perspective de pouvoir remédier lui-même à la carence protéinique de sa ration alimentaire ne constitue pas, en général, pour le paysan africain, une motivation suffisante pour l'inciter à persévérer dans un effort entrepris parfois avec enthousiasme, mais pas toujours en parfaite connaissance de cause. A cette raison s'en est ajouté très souvent un certain nombre d'autres : difficulté d'exploiter des étangs mal construits et mal aménagés, absence ou insuffisance d'aide et de conseils, difficulté d'assurer un encadrement actif et compétent, déception devant les résultats médiocres obtenus.

Beaucoup de pisciculteurs par conséquent ont abandonné; c'était, en général, les moins évolués au point de vue agricole. D'autres, au contraire, parmi les plus évolués, ont persévéré lorsqu'ils avaient la possibilité de vendre au moins une partie de leur production de poisson, d'en tirer un revenu en argent et de passer par conséquent, dans une certaine mesure, d'un système de pisciculture familiale de subsistance à un système de pisciculture artisanale.

La pisciculture artisanale utilisant les méthodes d'élevage de tilapia par classes d'âge mélangées ou séparées, constitue donc un système plus perfectionné que la pisciculture familiale de subsistance surtout si elle est plus ou moins intégrée à une exploitation agricole. Mais, employant les mêmes méthodes d'élevage et les mêmes poissons, elle est encore plus sensible à leur inconvénient majeur: celui de fournir une production constituée essentiellement par des poissons de très petite taille qui n'intéressent, en général, que médiocrement le pisciculteur et qui ont une faible valeur marchande.

Les possibilités d'améliorer ces méthodes par l'emploi d'un poisson prédateur paraissent assez réduites, car conduire une pisciculture d'équilibre est chose difficile, à moins que l'on ne dispose d'un apport d'alevins de l'extérieur.

Les possibilités de les remplacer par des élevages monosexes des espèces de tilapia habituellement utilisées se heurtent à la difficulté d'opérer un triage convenable des sexes sur des poissons n'ayant pas encore atteint la maturité sexuelle. Il faut attendre celle-ci, ce qui allonge la durée des élevages.

On est ainsi amené à conclure que les espèces sauvages de tilapia ne constituent pas de bons poissons de pisciculture. Elles n'ont pas évidemment été toutes essayées, mais rien ne permet de penser que celles qui ne l'ont pas été se comporteraient de façon très sensiblement différente.

C'est ce qui conduit à envisager d'autres systèmes de pisciculture employant d'autres méthodes et d'autres poissons (tilapia hybrides monosexes, Heterotis niloticus, carpe) pour lesquels on en est pratiquement encore à la phase expérimentale.

Ces systèmes de pisciculture prévoient l'utilisation de méthodes dans lesquelles les opérations d'alevinage et de production sont effectuées dans des étangs distincts. L'expérience montre que les opérations d'alevinage ne pourront être réalisées, au moins dans un proche avenir, que dans des installations et par des techniciens spécialisés. On aboutit donc à des systèmes dans lesquels les pisciculteurs se contenteront d'effectuer les opérations de production. Ils devront se procurer les alevins nécessaires auprès de stations qui, au moins au début, dépendront des services gouvernementaux. Il en résultera un double avantage. La tâche des pisciculteurs sera relativement simple. Les relations qu'ils devront avoir obligatoirement avec les stations spécialisées permettront d'exercer plus facilement sur eux une action d'encadrement efficace. Le rôle des stations apparaît donc primordial.

5 ORIENTATIONS POUR L'AVENIR

La pisciculture en étang, quels que soient les systèmes et les poissons utilisés, n'est possible que dans un milieu physique permettant la construction d'étangs et leur alimentation en eau. Ce milieu peut toutefois être plus ou moins favorable et moins il l'est, plus la tâche du pisciculteur est difficile.

D'autre part, l'expérience de ces quinze dernières années prouve que la pisciculture trouve en Afrique des possibilités de développement intéressantes dans un milieu humain de préférence relativement évolué au point de vue agricole et qui tire un revenu en argent d'une partie au moins de sa production de poisson.

Nous pensons donc que, contrairement à ce qui s'est produit dans les débuts de la pisciculture africaine alimentaire, où cédant à la tentative de faire des miracles, on a souvent construit des étangs un peu n'importe où et n'importe comment, il faut, dans un avenir proche, n'envisager les actions de développement et de vulgarisation que là où le milieu physique est très nettement favorable et là où le milieu humain est relativement évolué au point de vue agricole.

Dans les régions où ces conditions n'étant pas réalisées, il apparaît cependant souhaitable, en l'absence de ressources nautrelles suffisantes de promouvoir une production de poissons, il nous paraît préférable, dans la mesure du possible, d'organiser cette production par la création de retenues d'eau artificielles plus ou moins vastes, ne nécessitant qu'un aménagement piscicole extensif, une surveillance facile et dont l'exploitation par la pêche sera assurée par les habitants du voisinage.

En ce qui concerne les systèmes de pisciculture, nous avons vu qu'on a été amené par les leçons de l'expérience, à s'orienter vers celui dans lequel les opérations d'alevinage et de production se font séparément, les pisciculteurs effectuant seulement les secondes. Il faut poursuivre dans cette voie, car avec ce système:

- on peut réaliser des productions de gros poissons calibrés commercialement intéressants;

- la tâche du pisciculteur est relativement facile;

- l'obligation dans laquelle il se trouve de s'adresser aux services de vulgarisation pour se procurer les alevins dont il a besoin crée automatiquement entre lui et ces services des relations très profitables.

Il faudrait donc, là où elles existent, orienter progressivement la pisciculture familiale et la pisciculture artisanale de tilapia par classes d'âge mélangées vers une pisciculture artisanale equienne pratiquée dans des étangs agrandis et mieux aménagés avec d'autres espèces plus adequates. L'intégration aussi étroite que possible de cette pisciculture dans une exploitation agricole doit évidemment être recherchée. Certains pays se sont déjà engagés dans cette voie, en particulier l'Uganda (Uganda Fisheries Department, 1965).

Nous ne pensons pas, par contre, qu'une pisciculture industrielle comme celle essayée à Panyam au Nigéria soit susceptible de développement dans un proche avenir, sauf dans certains cas limités.

L'orientation que nous venons d'envisager implique évidemment l'existence de services de vulgarisation et d'encadrement disposant de stations d'alevinage spécialisées capables de fournir aux pisciculteurs les alevins nécessaires. La quasi inexistence de ces services ou la faiblesse des moyens dont ils ont disposé dans le passé sont en partie responsables de beaucoup d'échecs. Il est certain que l'importance des actions de développement et de vulgarisation entreprises doit être étroitement en rapport avec leurs possibilités.

L'emploi d'un système de pisciculture créant, du fait de la fourniture d'alevins, des liens étroits entre eux et les pisciculteurs ne peut que faciliter l'observation de cette règle.

Il est bon d'ajouter cependant qu'il est souhaitable de voir se créer, mais sans doute dans un avenir un peu plus lointain, des entreprises artisanales privées se consacrant à la production d'alevins comme cela existe dans d'autres régions tropicales et spécialement dans le Sud Est asiatique.

En ce qui concerne enfin les poissons utilisables par la pisciculture africaine, on peut faire les remarques suivantes:

Si les espèces de tilapia sauvages ne sont pas de bons poissons de pisciculture, elles constituent certainement, du fait de leur plasticité, un matériel de base précieux pour la création par hybridation et sélection de variétés ou de races intéressantes pour l'élevage. Des hybrides permettant la réalisation d'élevages monosexes ont déjà été obtenus. Ils ne concernent, pour le moment, que des espèces microphages. Il serait d'un grand intérêt d'en créer à partir des espèces macrophytophages compte tenu des facilités qu'ils pourraient offrir en matière d'alimentation artificielle.

La Carpe commune a maintenant acquis droit de cité dans plusieurs régions d'Afrique; elle mérite certainement d'être utilisée sur une plus large échelle dès que les mises au point nécessaires à la production d'alevins en grande quantité auront été faites.

L'utilisation de _Lates niloticus_ n'a été envisagée, jusqu'à présent, qu'à titre secondaire pour contrôler la reproduction des tilapia. Il pourra peut-être, dans l'avenir, constituer l'espèce principale d'élevages destinés à fournir un produit de haute valeur commerciale.

D'autres espèces africaines qui paraissent intéressantes à cause de leur croissance et de leur régime alimentaire mériteraient d'être essayées, ou réessayées, en particulier certains _Citharinus_ et _Distichodus_. Jusqu'à présent, leur reproduction en étangs n'a pas pu être obtenue, mais on pourrait tenter de la provoquer en reproduisant les conditions naturelles des cours d'eau (Wurtz, 1961).

Pour les espèces exotiques, l'introduction en Egypte du *Ctenopharyngodon idella* (grass carp) a été recommandée (Wunder, 1963). Le gros intérêt de ce poisson est sa croissance rapide et son régime alimentaire macrophytophage.

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VIII/E-1

THE CULTURE OF CATFISH (CLARIAS SPP.) IN THAILAND

by

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Abstract

The authors review all the available information pertaining to the breeding of Clarias sp. The methods include induced spawning by hormone injection, hatching, care of fry and fingerlings, and preparation of ponds for culture of the fish.

These methods are being accepted by Thai fish farmers and are expected to be practised widely in Thailand in the future.

L'ELEVAGE DES POISSONS-CHATS (CLARIAS SP.) EN THAILANDE

Résumé

Les auteurs passent en revue tous les renseignements disponibles concernant l'élevage des *Clarias* sp.: méthodes de frai provoqué par injection d'hormones, éclosion, soins à donner aux larves et aux alevins et préparation des étangs de pisciculture.

Les méthodes préconisées sont en train d'être adoptées par les pisciculteurs Thai et on s'attend à ce qu'elles se répandent largement en Thaïlande à l'avenir.

EL CULTIVO DE BAGRES (CLARIAS SP.) EN TAILANDIA

Extracto

Los autores examinan toda la información de que se dispone acerca de la cría de *Clarias* sp. Los métodos comprenden el desove provocado mediante inyecciones de hormonas, incubación, cuidado de jaramugos y de pececillos pequeños y preparación de estanques con fines piscícolas.

Estos métodos los están aceptando los agricultores que se dedican a la piscicultura en Tailandia y se espera que se practiquen también ampliamente en el futuro.

1 INTRODUCTION

Catfish, locally known as pladuk, belong to the family Clariidae (Fig. 1). There are five species in Thailand, of which only two, pladuk oui, *Clarias macrocephalus*, and pladuk dan, *C. batrachus*, are popular (Smith, 1945). These two species can be distinguished by the shape of the occipital process, which is more pointed in *C. batrachus* than in *C. macrocephalus* (Fig. 2). Both species are regarded as very delicious fish in Thailand. *C. macrocephalus* seems to be liked better than *C. batrachus* for its more tender meat, but when cultured *C. batrachus* grows faster than the other species (Pawapootanon, 1965). However, Thai fish farmers are very fond of both species because of their ability to survive in all kinds of water, the small area required for their culture, and because their market price is always higher than that of other fresh-water fish.

2 GENERAL BIOLOGY OF CATFISH (*CLARIAS BATRACHUS* AND *C. MACROCEPHALUS*)

2.1 General distribution

The catfish are widely distributed, being found in all fresh-water areas, even in almost dry pools, as they have accessory organs to breathe atmospheric air (Smith, 1945). They can live for a long time out of water or in waters of very low oxygen content, and can also live in brackish water (Tongsanga *et al.*, 1963).

2.2 Food habits

These catfish feed on worms, insects and shrimps, but since they prefer to eat decayed protein food they are sometimes classified as scavengers. However, when reared in ponds, they can be trained to feed on rice mixed with rice bran, fish meal or chopped vegetables, the fish always coming up to take feed near the water surface (Fig. 3).

2.3 Mating and egg-laying

2.3.1 Differentiation of mature male and female

The sex of these catfish can be distinguished easily when the fish reach a length of 20 cm or are one year old, for the anal papilla of the male is pointed, while that of the female is oval in shape (Fig. 4). During the spawning season the belly of the female becomes larger than that of the male.

2.3.2 Time of spawning

Wanichakorn (1957) stated that *C. batrachus* spawn during the rainy season, between May and October, for the fish fry were not found at other times of the year. However, Tongsanga (1962) mentioned that this species can spawn all the year round if they have fresh water.

2.3.3 Egg-laying

C. macrocephalus spawn in paddy fields during the rainy season (Tongsanga *et al.*, 1963). The female makes a small round hollow nest, about 30 cm in diameter and 5 to 8 cm deep, in the grassy bottom in shallow water, 20 to 30 cm deep. The eggs are deposited in the nest and, being adhesive, they adhere to the grass near it. After spawning the male guards the nest while the female stays nearby.

C. batrachus usually spawn in deeper water than *C. macrocephalus*, preparing a horizontal hole in the bank below the water surface. The size of the hole depends on the size of fish, generally it is about 20 cm across and 25 cm deep. The eggs deposited in the hole

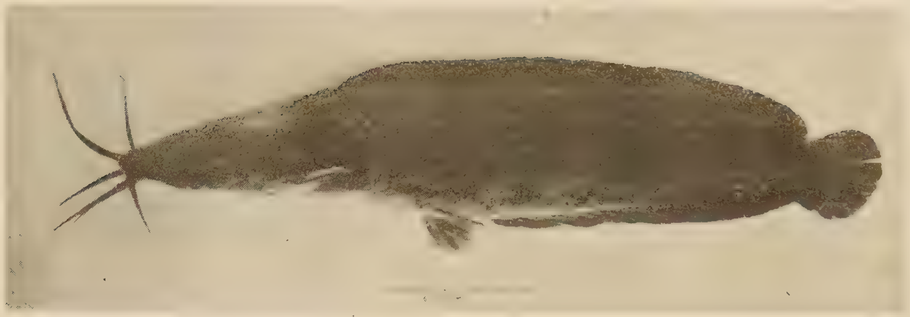

Fig. 1 Clarias macrocephalus Gunther

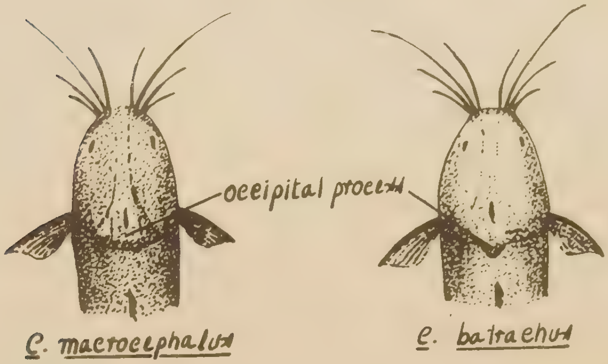
occipital process
C. macrocephalus
C. batrachus

Fig. 2 Difference in the shape of the occipital process of C. macrocephalus and C. batrachus

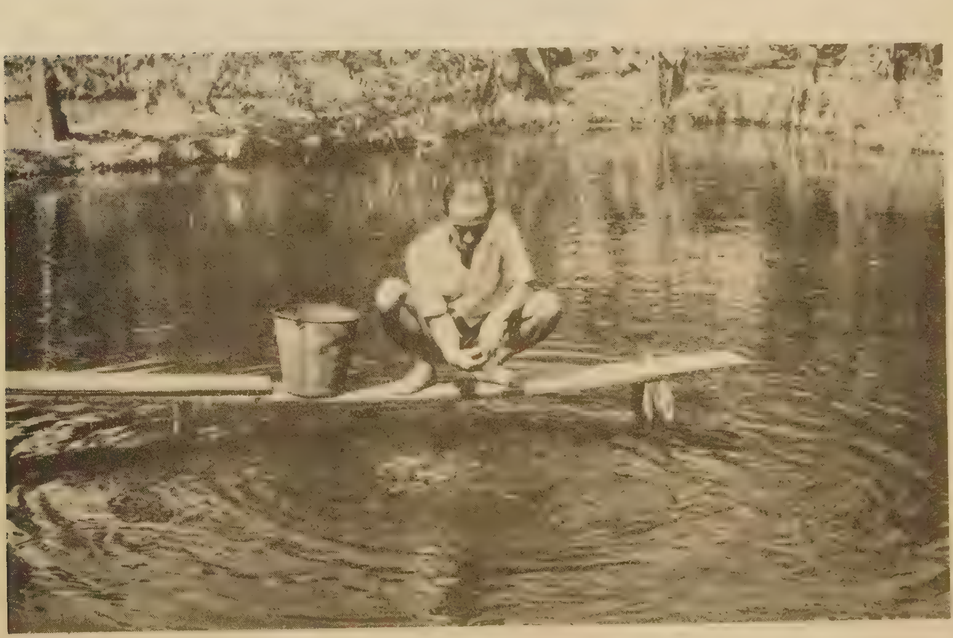

Fig. 3 Feeding of catfish in ponds

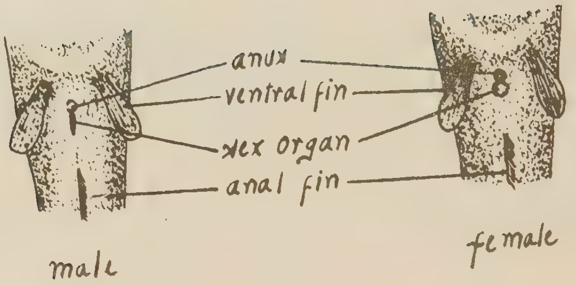
anus
ventral fin
sex organ
anal fin
male
female

Fig. 4 Sex organ of C. macrocephalus and C. batrachus

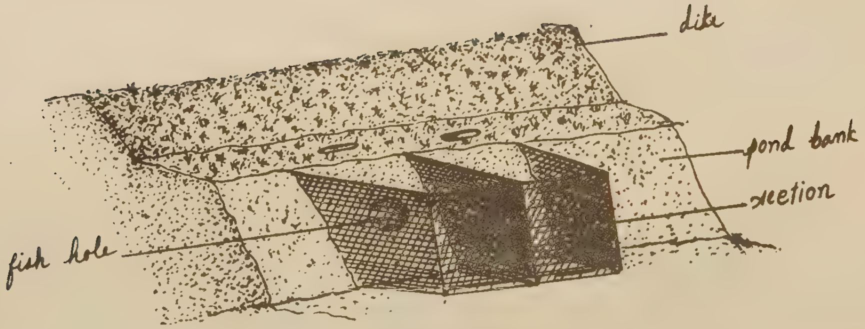
dike
pond bank
section
fish hole

Fig. 5 Device used for pond breeding of catfish

adhere to the grass and sometimes to the soil surface. The round eggs are yellowish-brown and 1.3 to 1.6 mm in size; they hatch within 20 hours at a temperature of 25 to 32.2°C.

3 METHODS OF CULTURE

Most catfish fry for stocking come from natural waters such as paddy fields, irrigation canals, swamps, etc. and very few from hatcheries. The price of the fry depends on their size; usually 100 fry, 2.5 cm in length, cost 5 baht (U.S.$ 1.00 = 20 baht) and 10 cm long, 25 baht. The farmers prefer to stock the big ones because the mortality rate is lower than that of the small ones, and also the time required for culture is shorter.

3.1 The collection of fry from natural waters

Maungboon (1961) stated that the fry collecting season begins in May and ends in October in the canals and ditches where the water is comparatively calm. The nests are found on the margins about 50 cm below the water surface, the breeders selecting places where grasses are available as the spawning ground. Before collecting the fry the collector has to check the spawning hole by hand to see whether the fish have yet spawned. If fry are present, a small fine-meshed hand net is used to transfer them into a fry container. Generally, 2,000 to 15,000 fry are found in one hole. The fry are then reared in a nursery pond until they reach a length of 5 cm. They are then transferred to a stocking pond or sold as fry for stocking. This collecting method yields approximately 50 million fry a year.

3.2 Breeding methods

3.2.1 Pond breeding

Although millions of fish fry are collected each year, these are still not enough for large-scale stocking and culturing purposes. The Thai Fisheries Department therefore tried to breed these fish in ponds. Wanichakorn (1957), Fisheries Officer of Chiengrai Fisheries Station, experimented on breeding C. batrachus. He prepared the breeding pond by dividing the margins into sections according to the number of breeding couples to be used. Each section was enclosed by a wire screen of 1 x 1.20 m in size (Fig. 5). In the centre of each section a horizontal hole 20 to 35 cm in diameter was dug on the margin some 20 to 25 cm below the water surface. The sections were then provided with some aquatic plants before the ready-to-breed couples were put in and the fish spawned seven to ten days later. About 2,206 to 5,400 fry were produced in one section. The newly hatched fry were then removed to the nursery pond where they were kept until they were about 5 cm long when they were transferred to a stocking pond.

Sidthimunka (1959) improved this method by making the hole in the margin resemble a natural spawning site and omitting the wire screen partition. Nests were examined for fish eggs and fry every three days for one month. The fish eggs and fry were brought in and placed in troughs or wooden tanks for hatching and rearing respectively. Under these conditions about 80 percent of the fish spawned. The number of fry from one couple was similar to that obtained by Wanichakorn.

3.2.2 Induced spawning

Tongsanga et al. (1963) experimented with intramuscular injections of pituitary extract to induce spawning in C. macrocephalus. He found doses of 13 mg induced spawning in 22 cm, 100 g fish and of 26 and 39 mg in fish of 23 to 30 cm, 100 to 190 g. The experiments were carried out at water temperatures of 25° to 32°C. The fish responded 14 to 16 hours after being injected. The fry, when examined two weeks later, averaged 3,814 per breeding pair (ranging from 449 to 17,046); by then they had completely absorbed the yolk sac and were 1.9 cm long.

We repeated Tongsanga's experiments between June and August 1965 using hormone doses of 26 and 39 mg per fish on fish of three size groups between 23 and 30 cm long. The experiment was conducted in aquaria 85 x 36 x 36 cm with water 15 cm deep. In each aquarium local plants (*Coix aquatica*) were placed for deposition of the eggs. Five experiments were made and between 60 and 80 percent of the fish spawned.

These experiments showed that *C. macrocephalus* can be induced to spawn in small aquaria by hormone injection. This proved easy to do but the techniques need further improvement.

3.3 Method of hatching

Catfish eggs hatch in troughs or hatching jars. They need shallow water and exposure to air. The water must be changed twice a day, in the morning and later afternoon. It is necessary to pick out the unfertilized eggs which are usually affected by mold. All the eggs hatched out within 20 hours at water temperatures of 26° to 33°C, and the yolk sacs were absorbed five days later.

3.4 Care of fry and fingerlings

Wanichakorn (1964) experimented on rearing young fry in an earth pond and found that (i) minute living organisms are the best food for the fry of early stage, and (ii) as many as 15,000 to 20,000 fry can be reared in a small space of 1 x 3 x 0.6 m without any mortality. Lerdprasert (1964) reported that in rearing 20,000 small fry in a basket of 1.2 x 1.5 x 0.9 m he fed them with three litres of zooplankton every morning plus 1 kg of fish flesh and 250 g of peanut cake in the afternoon. After two weeks the fry had grown from 1.5 to 4.3 cm long. At this size the fry can be transported to the stocking ponds. Damrongrat (1962) also confirmed that small fry need minute zooplankton at the early stages of growth and boiled fish meat can be used two or three weeks later. *Clarias* fry survive better in shallow water about 10 to 18 cm deep; if the water is too deep the fry cannot swim to the surface and may die soon.

3.5 Method of culturing in ponds

Ponds used for culturing these catfish vary in size and shape; they are usually about 100 to 1,000 m^2 and 1.5 to 3.0 m deep; rectangular ponds are preferred as they can be more easily fished.

3.5.1 Preparation of the pond

Ponds are prepared as for other pond fish, but the inner side of the bunds must be made as firm as possible by pressing with heavy log or board; otherwise these catfish are liable to climb over or burrow through the pond bank and escape. Ponds are fenced with bamboo cane or wire screens to a height of about 50 cm, or if the pond is located near the river, wood planks are used. Water is allowed to fill the pond by passing through a screen to about 1 m in depth at the beginning; the depth is gradually increased as the fish grow, reaching an optimum depth of 2 to 3 m. If the fish remain small, one application of farmyard manure is made, but if they grow well no manure is added. Thirty kg of manure per 100 m^2 of pond area is the usual amount used by the fish farmers.

3.5.2 Rate of stocking

It has been found that the rate of stocking in ponds 2 to 3 m deep should be 50 fish/m^2 water surface when 7 to 10 cm fish are used, or more if smaller fish are stocked. Late afternoon or early morning is the best time for stocking.

3.5.3 Feeds and feeding

Feeds such as meat or fish offal and by-products of canning factories are chopped into small pieces suitable for the fish to swallow. Boiled rice mixed with vegetable and peanut cake are added if enough offal is not available. C. macrocephalus and C. batrachus are fed once in the night and twice in the day. Feed is given by hand, by dropping small amounts into the pond until the fish stop feeding.

3.5.4 Care of ponds

The fish have the habit of digging and stirring up the pond bottom. To prevent this a small water pipe is installed in the middle of the pond and the water allowed to run slowly. This attracts the fish to the surface and therefore the chances of their digging at the bottom are minimized.

3.5.5 Harvesting

The fish are harvested when about 25 cm long (200 g weight) usually after culturing for about four months (stocking with 10 cm fingerlings). The pond is drained partially and fish are captured by seine and scoop nets as soon as the water level is low enough. The harvested fish are transported to markets in tin cans with a small amount of water.

Pawapootanon (1965) made a survey on five C. batrachus farms in the vicinity of Bangkok and reported that the most successful farm yielded 4,300 kg, valued at 43,000 baht (2,150 $ U.S.) after five months of culturing in a pond of 20 x 20 x 2.5 m in size, in which 600 kg of fingerlings (1 kg of fingerlings comprising 80 fish, 6.0 cm in length) were stocked in September 1964. The fish were intensively fed as described above. Based on this yield it is estimated that it would be possible to produce as much as 107,500 kg/ha fish from 656,250 kg of feed. The conversion ratio is approximately 6:1.

These fish can also be cultured in floating baskets and in combination with poultry.

4 CONCLUSIONS

Clarias batrachus and C. macrocephalus are easy to culture as they grow very fast, give a high yield, thrive well in a variety of conditions, are hardy (the living fish being taken to market in tins without mortality) and command the highest market prices. They give the highest production of any fish in Thailand.

Fingerlings for stocking can be obtained from natural waters, breeding them in ponds, or by induced spawning in small aquaria using hormone injections.

Fifty fingerlings/m^2 pond surface is the optimum stocking rate. Fed on animal offal mixed with rice and vegetables the growth averages 40 g/month, and they reach harvestable size in four or five months. Two or three crops can be harvested a year. The food conversion ratio is about 6:1. The cost of feed to produce 1 kg fish was about 5 baht (25 U.S. cents) and the sale price per 1 kg fish was 8 to 10 baht (40 to 50 U.S. cents). Production of 107.500 kg/ha should be possible using about 656,250 kg feed.

5 ACKNOWLEDGEMENT

Thanks are due to Dr. S.W. Ling, FAO/TA Regional Fish Culturist, Bangkok and Mr. Andhi P. Isarankura, Fisheries Biologist, for their kind advice and assistance in the preparation of this paper.

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A PRELIMINARY REPORT ON POND CULTURE OF THE GIANT FRESH-WATER PRAWN, MACROBRACHIUM ROSENBERGII DE MAN

by

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Abstract

The authors report the results of an experiment to observe the growth of fingerlings of *Macrobrachium rosenbergii* de Man, when fed on chopped fresh carp at the rate of 5 percent of body weight of the prawns twice daily.

The results indicated that 65 percent of the fingerlings with initial lengths ranging from 5.3 to 7.9 cm attained marketable size (30 g per prawn) at the end of the six month experimental period. The food conversion for the smaller fingerlings was on the average better than that of the larger fingerlings, indicating better utilization of the food.

RAPPORT PRELIMINAIRE SUR L'ELEVAGE EN ETANG DE LA CREVETTE GEANTE D'EAU DOUCE, MACROBRACHIUM ROSENBERGII DE MAN

Résumé

Les auteurs rendent compte des résultats d'une expérience visant à observer la croissance d'alevins de *Macrobrachium rosenbergii* de Man, nourris deux fois par jour avec de la chair de carpe fraîche hachée, à raison de 5 pour cent du poids des crevettes.

Les résultats indiquent que 65 pour cent des alevins, ayant une longeur initiale allant de 5,3 à 7,9 cm, ont atteint une taille marchande (30 cm) à la fin de la période expérimentale de six mois. Le coefficient de conversion alimentaire des petits alevins était en moyenne supérieur à celui des gros alevins, ce qui indique qu'ils tiraient meilleur parti de l'alimentation fournie.

VIII/E-2

INFORME PROVISIONAL SOBRE EL CULTIVO EN ESTANQUES DEL CAMARON GIGANTE DE AGUÁ DULCE, *MACROBRACHIUM ROSENBERGII* DE MAN

Extracto

Los autores exponen los resultados de un experimento realizado con objeto de observar el crecimiento de ejemplares pequeños de *Macrobrachium rosenbergii* de Man, al alimentarlos dos veces al día con carpas frescas picadas, a razón del 5 por ciento del peso del cuerpo de los camarones.

Los resultados indicaron que el 65 por ciento de tales crías con tamaños iniciales de 5,3 a 7,9 cm. alcanzaron tamaños comerciables (30 g por camarón) al final del período experimental de seis meses. El índice de conversión del alimento in término medio, superior al de las crías más grandes, lo que indica un mejor aprovechamiento del alimento.

1 INTRODUCTION

Macrobrachium rosenbergii de Man, known in Thailand as "Koong Yai" (Koong = Prawn Yai = big), is a giant fresh-water prawn. A male prawn found in Bangkok market on 6 June 1964 measured 25 cm (from post-orbital to the tip of telson) and weighed 470 g. *M. rosenbergii* is highly esteemed as food by people of all races. The demand for this prawn in Thailand is increasing, but the natural production is declining every year, due both to natural environmental causes as well as over-fishing. Therefore, methods of increasing production of this prawn were considered, and attempts were made to use young prawns from natural waters for experimental culture.

In 1956, 300 young prawns of *M. rosenbergii* collected downstream of Choa Phya Dam were transferred to an old earth pond (20 x 15 x 2 m) at Bangborapet Fisheries Station. The prawns were fed with baked tilapia. After four months only 39 prawns survived. The average growth of the survivors was about 60 g, but the mortality rate was estimated to be 87 percent. In 1963, the Bangkhen Fisheries Station reported the result of culturing this prawn in a cement pond of 64 m^2 and 50 cm deep, in which 200 fingerlings, 5.7 cm in length, were stocked. Boiled tilapia was used to feed the young once a day. At the end of the experiment, the prawns were measured in order to find their average growth. This was found to be 9.59 cm in length and 27.10 g in weight, an increase of 4.02 cm in length and 24.40 g in weight. The total mortality was 11 percent.

These experiments showed that *M. rosenbergii* could well be used for pond culture, provided that techniques and culture methods are improved. Therefore in 1965, an experimental program for the culture of *M. rosenbergii* at Chainat Fisheries Station was laid out with the help of Dr. A. Witt, Jr., an FAO Fisheries Expert.

2 METHOD AND MATERIAL

Test was made in aquaria to find out the amount of food needed to feed the young prawns per day, since overfeeding may cause pollution and shortage of food may lead to cannibalism. It was found that the fingerlings fed on chopped fresh carp flesh at the rate of about 5 percent of body weight every 12 hours. This feeding rate was used throughout the experiment.

Four new earth ponds (B_7, B_8, B_9, B_{10}) all of which were 20 x 10 x 1.5 m in size were used (Fig. 1). Each pond had an outlet and an inlet covered with fine screens. One week before stocking, the ponds were drained and allowed to dry. Lime was applied to kill predators when the ponds were emptied.

In the first two ponds (B_7 and B_8), a pile of bricks was placed on the bottom at one side to provide shelters during the moulting period. For the same reason, a bunch of dry branches was placed in ponds B_9 and B_{10}.

The fingerling prawns of *M. rosenbergii* were collected from downstream of Choa Phya Dam at night by means of hand nets on 10 May 1965, and were then transferred to a plastic floating basket. On 21 May 1965, 300 young prawns of size 5.7 - 7.9 cm (measured from post-orbital to tip of telson) were selected from the floating basket for culturing in each prepared pond. Chopped fresh carp flesh was given to the prawns at the rate of 5 percent of their body weight, twice a day, at 08.00 a.m. and 05.00 p.m. The food was placed in a wooden plate which was lowered to the bottom. Each pond had six feeding plates.

The growth rate was determined by sampling 25 prawns from each pond every two weeks. The ponds were drained to study the growth and survival rates at the end of the third and sixth months of the experiment.

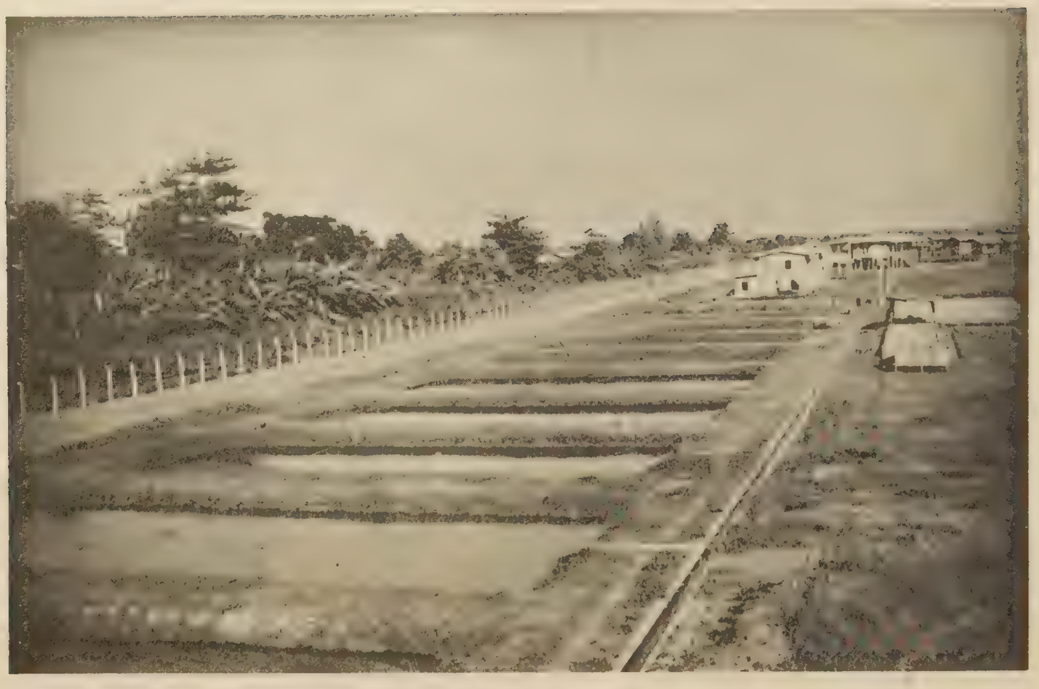

Fig. 1 The experimental ponds at Chainat Fisheries Station

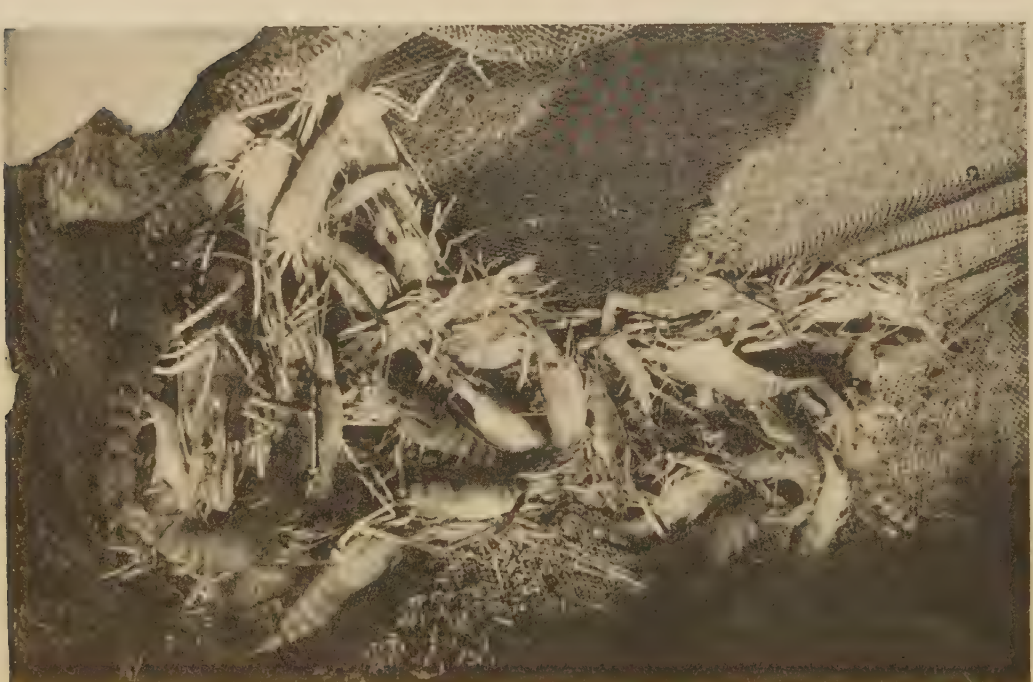

Fig. 2 The harvested prawns

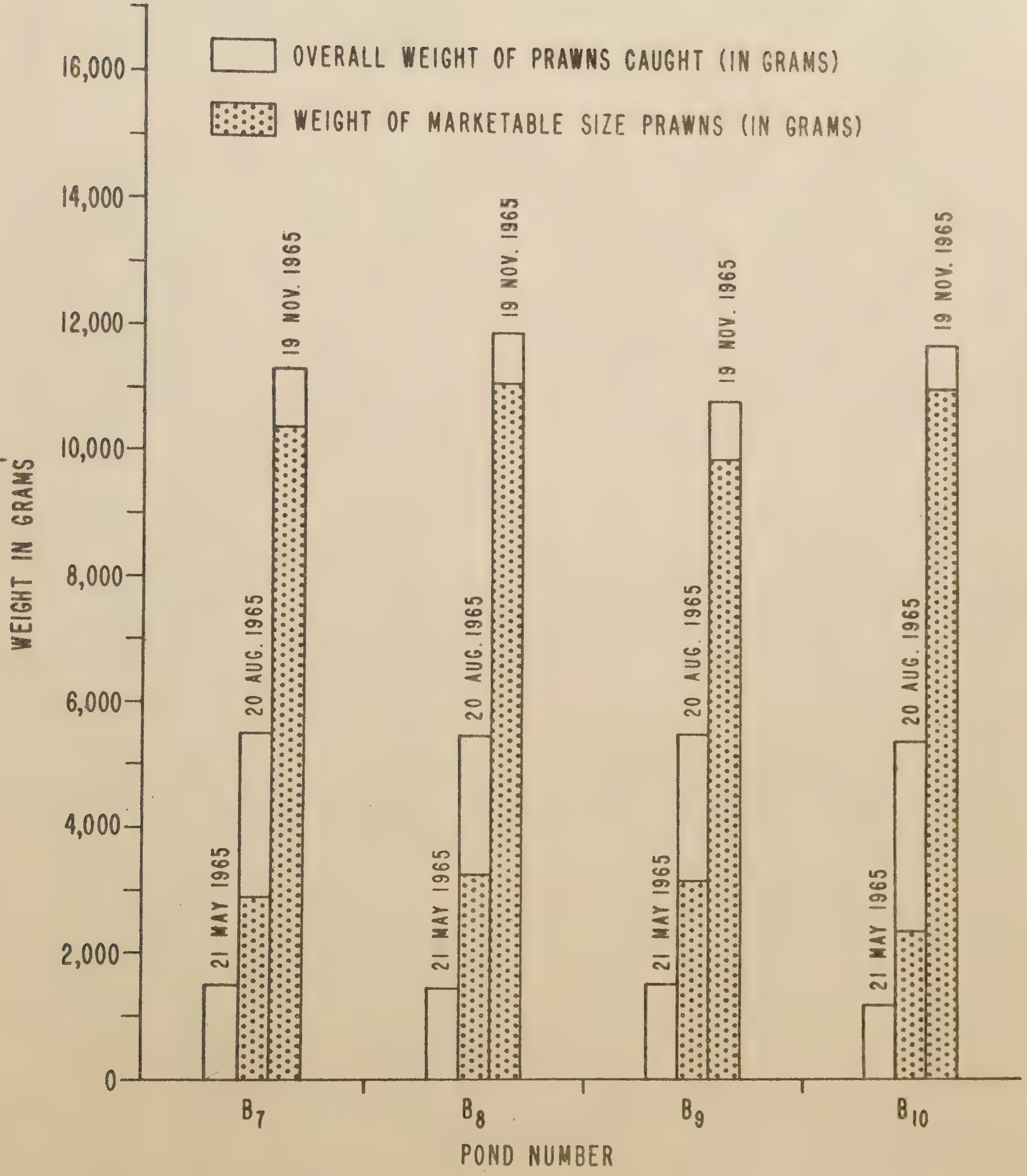

Fig. 3 Comparison of total weight between marketable and unmarketable size prawns among different ponds after being harvested

Table I

Results of experiment during the first three months of culture

Pond no.	Stocking(21 May 1965)			Harvest (20 Aug. 1965)			Mortality rate (percent)	Weight of food used (g)	Conversion ratio	Weight of competitors caught (g)
	Number	Size range (cm)	Total wt (g)	Number caught	Size range (cm)	Total wt (g)				
B_7	300	5.7-7.9	1,563.5	282	6.3-15.2	5,516.0	6.0	27,941	7.1:1	3,987.0
B_8	300	5.3-7.9	1,459.0	290	6.0-13.8	5,461.0	3.3	26,015	6.5:1	3,691.0
B_9	300	5.3-7.7	1,548.0	291	6.3-13.9	5,526.0	3.0	24,887	6.2:1	2,862.0
B_{10}	300	5.3-7.8	1,235.0	296	5.8-13.4	5,387.0	1.3	24,713.5	6.0:1	8,561.0
total	1200	-	5,805.5	1,159	-	21,890.0	-	103,556.5	-	19.101.0
average	300	5.4-7.8	1,451.4	289.7	6.1-14.0	5,472.5	3.4	25,889.125	6.5:1	4,775.25

Table II

Results of experiment during the last three months of culture

Pond no.	Stocking (21 May 1965)			Harvest (20 Aug. 1965)			Mortality rate (percent)	Weight of food used (g)	Conversion ratio	Weight of competitors caught (g)
	Number	Size range (cm)	Total wt (g)	Number caught	Size range (cm)	Total wt (g)				
B_7	282	6.3-15.2	5,516.0	220	7.0;15.9	11,345.0	21.9	77,770.0	12.3:1	2,492.0
B_8	290	6.0-13.8	5,461.0	238	6.7-16.8	11,954.0	17.9	81.075.0	12.5:1	1,898.0
B_9	291	6.3-13.9	5,526.0	202	7.1-16.5	10,880.0	30.5	88,751.0	16.6:1	1,816.0
B_{10}	296	5.8-13.4	5,387.0	228	7.1-16.9	11,757.0	22.9	81,354.0	12.8:1	1,858.0
Total	1159	-	21,890.0	889	-	45,936.0	-	322,950.0	-	8,064.0
Average	2897	6.1-14.0	5,472.5	222	7.0-16.5	11,489.0	23.3	80,737.5	13.6:1	2,016.0

The aquatic competitors of prawns in ponds, such as small shrimps and paddy field crabs, were taken out by lift net once or twice a week and weighed. The pond water temperature was taken in the morning and late afternoon every day and during the experiment was found to range from 26° to 33°C.

3 RESULTS

Results of the experiment are given in Tables I and II. Prawns attaining marketable size (over 30 g each, Fig. 2) numbered 267 out of 1,159, and 580 out of 888 harvested prawns. A comparison of total weight of marketable and unmarketable prawns from each pond at harvest is shown in Fig. 3. The average growth of M. rosenbergii is shown in Fig. 4. Ninety-nine percent of the harvested prawns were male. Although shelters are necessary to the prawns during moulting, no difference in efficiency was noticed between a pile of bricks and a bunch of dry branches as shelter for the prawns. The food conversion ratio in the second three-month period (Table II) was double that of the first. This indicated that as the M. rosenbergii grew their ability to convert food for gaining body weight is reduced. The mortality rate was high after restocking and culturing in the last three months, because the pond water was polluted by the leftover food which had accumulated and decayed. M. rosenbergii were very sensitive to this pollution. When affected, they usually crawl up near the surface and soon die. To prevent this, the pond water was immediately changed.

Aquatic competitors comprised almost all the small shrimps, of 27,165 g total weight, which shared the food given to M. rosenbergii during the experiment.

Since young prawns are available in great quantity in downstream of the Chao Phya Dam, their collection is easy. Thus, M. rosenbergii culture is possible for fish farmers if the techniques of culture are developed. This may become a popular pond culture practice in Thailand in the future.

4 ACKNOWLEDGEMENT

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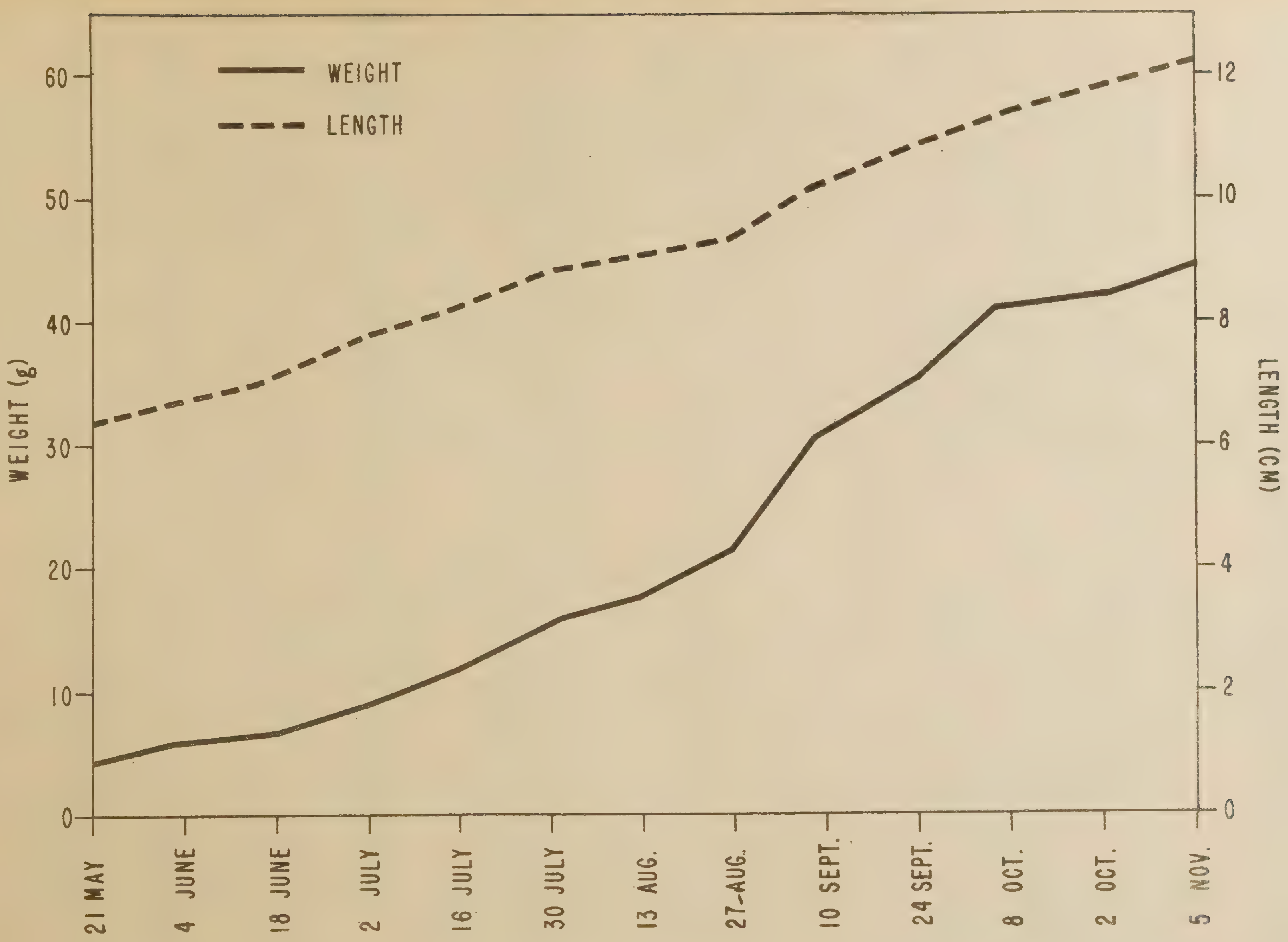

Fig. 4 Average growth of M. rosenbergii in experimental ponds every two weeks

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RAISING OF RAINBOW TROUT (SALMO GAIRDNERI) TOGETHER WITH CARP (CYPRINUS CARPIO) AND OTHER FISHES

by

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Abstract

Rainbow trout (Salmo gairdneri) are used to increase production from carp fattening ponds in Poland and Czechoslovakia. Liked for their high market value, they are especially useful as predators in ponds with abundant trash fish and where "wild spawning" of carp occurs; unlike pike, they live in the open water as well as the marginal zone of the pond.

One-year-old trout are generally stocked at 1,200-1,500/ha, i.e. to 15 percent of the carp stock, giving a yield of 65 to 84 percent of two-year-old fish. Trout production is generally 20 to 40 kg/ha, even in conditions of multi-species stocking.

Physical and chemical conditions limiting the use of trout in carp ponds are discussed; they need 5 to 6 ml/l dissolved oxygen, and they grow best at 16 to 18°C but can stand higher temperatures. Growth depends on the quantity of natural food available.

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ELEVAGE DE LA TRUITE ARC-EN-CIEL (SALMO GAIRDNERI) AVEC LA CARPE (CYPRINUS CARPIO) ET D'AUTRES POISSONS

Résumé

Des truites arc-en-ciel (Salmo gairdneri) ont été utilisées pour accroître la production dans des étangs d'engraissement de carpes en Pologne et en Tchécoslovaquie. Recherchées pour leur valeur commerciale élevée, ces truites sont particulièrement utiles en tant que prédateurs dans les étangs où abonde du poisson sans valeur marchande et où les carpes se reproduisent naturellement de manière excessive; contrairement aux brochets, elles vivent en pleine eau aussi bien que dans les zones marginales de l'étang.

On déverse en général dans l'étang 1,200 à 1,500 truitelles d'un an par ha, c'est-à-dire 15 pour cent de la charge de carpes, ce qui donne un rendement de 65 à 84 pour cent de poissons de deux ans. La production de truites se situe généralement entre 20 et 40 kg/ha, même dans des conditions d'élevage mixte.

L'auteur examine les conditions physiques et chimiques qui limitent l'emploi de truites dans les étangs de carpiculture: les truites ont besoin de 5 à 6 ml/l d'oxygène dissous et prospèrent entre 16° et 18°C, mais elles peuvent supporter des températures plus élevées. Leur croissance dépend de la quantité de nourriture naturelle disponible.

CRIA DE TRUCHAS ARCO IRIS (SALMO GAIRDNERI) JUNTO CON CARPAS (CYPRINUS CARPIO) Y OTROS PECES

Extracto

Las truchas arco iris (Salmo gairdneri) se emplean para aumentar la producción de los estanques de cría de carpas en Polonia y Checoeslovaquia. Apreciadas a causa de su elevado valor en el mercado, son especialmente útiles como predadores en aquellos estanques en que abundan los peces corrientes y en los que las carpas desovan desordenadamente; a diferencia del lucio, viven tanto en las aguas abiertas como en las zonas marginales del estanque.

Generalmente hay 1.200-1.500 truchas de un año por hectárea, es decir un 15% de la población de carpas, que proporcionan un rendimiento del 65 al 84 por ciento de ejemplares de dos años. La producción de truchas es generalmente de 20 a 40 kgs/ha, incluso en aquellas condiciones en que conviven muchas especies.

Se examinan las condiciones físicas y químicas que limitan el empleo de truchas en los estanques de carpas; necesitan de cinco a seis ml/l de oxígeno disuelto, y crecen mejor a temperaturas de 16 a 18°C pero pueden soportar temperaturas más elevadas. El crecimiento depende de la cantidad de alimento natural existente.

1 INTRODUCTION

The raising of the productivity of ponds is the most important problem of present day pond pisciculture. It is being solved mainly by (i) increasing the stocking density of the single-species stock. In this case intensive feeding is adopted. There is a tendency here to switch over to a stall system of rearing different species of fish; and (ii) by multispecies stocking with species of different feeding behaviour for maximum utilization of the natural productivity potential of the water-body.

According to Sukhoverkhov (1963) during the rearing of the two-year-old carp in a single-species stock the carp eat only some species of bugs and beetles so the phytoplankton and higher aquatic vegetation, detritus, zooplankton, larvae and mature beetles (Coleoptera), dragon-flies (Odonata), leeches (Hirudinea), tadpoles and others are hardly used.

At present pond farms in the U.S.S.R. generally use a combination of species from the Far East, i.e. the silver carp (*Hypophthalmichthys molitrix*), the bighead (*Aristichthys nobilis*) and the grass carp (*Ctenopharyngodon idella*), or other European species such as coregonids, - the peled (*Coregonus peled*) and the vendace (*Coregonus albula*), or cyprinids - the crucian carp (*Carassius auratus gibelio*) and the orfe (*Leuciscus idus* var. *orphus*). The predatory species pike (*Esox lucins*) and pike perch (*Lucioperca lucioperca*) are also reared together with carp.

In connection with the development of trout farming, more and more attention is being given to the rainbow trout (*Salmo gairdneri*) as a compatible fish for carp ponds (Eleovsky, 1946; Martyshev, 1963; Sukhoverkhov, 1963). In Poland, Czechoslovakia and other European countries also the trout is reared in carp fattening ponds (Nesis, 1958; Goscinski, 1963).

2 PROPORTIONS OF TROUT TO CARP

The stocking rate of one-year-old trout is usually about 10-15 percent of the stock of carp. The yield of two-year-olds constitutes from 65 to 84 percent of the number released. The productivity of the trout amounts to 20 to 30 kg per ha (Sukhoverkhov, 1963; Lavrovsky, 1965) and even to 50 kg per ha (Goscinski, 1963).

Pisciculturists' preference for the rainbow trout rather than for other predatory fishes is accounted for by the flavour of its flesh and its high market price. In large carp rearing ponds the trout is more productive than the pike, as the trout, unlike the pike, lives not only in the marginal zone of ponds but in the open water as well.

Unsilted ponds slightly overgrown with aquatic vegetation are good for rearing trout. One-year-old specimens of the rainbow trout are raised in special trout rearing farms and are released in carp fattening ponds. The number stocked is about one third the number of carps, i.e. 1,200 to 1,500 per ha. The ponds should preferably be 2.5 to 3.0 m deep. It is possible to use ponds where the carp stock is 2,000-2,500/ha if there are springs at the bottom of the pond, or some other way of introducing running water if oxygen depletion occurs. However, in this case, the rate of trout growth is slow, as the carp consumes most of the food.

It is especially desirable that the trout should be introduced into ponds where there is an abundance of trash fish. Some workers have reported that the trout prefers the verkhovka (*Leucaspius delineatus*) to other fishes, but usually it devours other small fishes too.

3 CONDITIONS LIMITING USE OF TROUT IN CARP PONDS

The growth rate of two-year-old rainbow trout in carp fattening ponds depends on the following main factors:

(i) the chemical composition of the water and especially "gas regime";

(ii) water temperature;

(iii) the food supply;

(iv) the size and weight of the fish used for stocking.

The observations made by Sukhoverkhov and Pisarenkova (1963) in the ponds of Moscow and Kursk regions helped to determine the chemical composition of water which allows the raising of the trout in carp rearing ponds. The trout can live and grow at colarity amounting to 128°, a water hardness equal to 4.1 to 7.5 German grades, oxygen content - down to 20.4 mg/l O_2, iron content - up to 0.9 mg/l Fe, phosphoric acid - up to 0.19 mg/l P_2O_5, chlorides - up to 36 mg/l Cl' and sulphates - up to 48 mg/l SO''_4.

The "gas regime" of carp rearing ponds is usually subject to sharp fluctuations. Ponds with an oxygen content equal to 5 to 6 ml/l O_2 can be used for rearing trout. However, short term (up to several hours) decreases in the content of oxygen down to 2.5 to 3.0 ml/l O_2 are also permissible. The content of free carbonic acid may vary within 2.5 to 15.0 ml/l CO_2 (Lavrovsky, 1965).

Many pisciculturists are of opinion that the trout can be reared only in cold water fish farms. However, the optimum temperature for the growth of the rainbow trout has been found to be 16-18°C. The trout continues to feed at temperatures up to 24°C and can stand short term rises of temperature up to 28°C.

Under unfavourable gas and temperature conditions the trout gather near the water inflow, or keep so close to the surface that their dorsal and caudal fins are above the water surface.

The quantity of natural food in ponds depends mainly on the density of the carp stock. When this is high the carp are compelled to feed on organisms to which they are unaccustomed, for instance on zooplankton and certain bugs. Sukhoverkhov and Pisarenkova (1963) observe that one-year-old specimens of the rainbow trout of a weight of 3 g in a two-fold stocking of carp gained as much as 121 to 125 g weight. In a three-fold stocking of carp one-year-old specimens of the trout weighing 7 g gained as much as 70.8 g weight, and in a five-fold stocking of carp their weight was only 40 g.

Sometimes to increase the food supply of the trout it is recommended to release into the ponds fry of the orfe (Leuciscus idus var. orphus) and the roach (Rutilus rutilus) which do not compete with the carp and at the same time are good food for the trout.

The rearing of the rainbow trout is especially desirable in the ponds where during the summer period the replenishment and foundation stocks of the carp are kept and where uncontrolled "wild" spawning may take place. Trout feeding on young carp not only grow well but also improve the feeding conditions for the carp spawners.

4 USE OF TROUT IN MULTI-SPECIES STOCKING

In 1964 we conducted an experiment in rearing two-year-old trout in two carp stock ponds of an area of 1.42 ha each. In addition to five-year-olds there were also younger carp (I+, II+, III+), the grass carp (Ctenopharyngodon idella) (I+, III+) and the silver carp (Hypophthalmichthys molitrix) (I+).

During the growing period the temperature of the water was 22°to 23°C, and for two months it was above 20°C. In spite of the fact that the oxygen regime was unfavourable for the trout and the oxygen content dropped to 3.0 ml/l O_2 the yield of trout in the autumn constituted 69.4 and 91.0 percent of the number released. The production of the trout made up 30.8 and 36.5 kg per ha or 4.7 and 6.3 percent of the total fish production.

The trout in pond 1 gained weight from 23.8 g to 160.5 g, and in pond 2 from 53.0 g to 235.0 g. Individual specimens weighed 485 g. The high growth rate of the trout is accounted for by the rich food supply. In the spring of 1965 some females of the trout matured and spawned (usually females of the trout mature at the age of three years). Many males also matured. It is of interest that in conditions of multi-species rearing the food niche of the trout remained intact, and it fed on its usual food organisms, such as bugs (Corixa sp.), larvae of caddis flies (Trichoptera), larvae and pupae of gnats and other dipterans (Glyptotendipes, Pseudochironomus etc.), daphnia, carp fry, frogs (Rana) and aerial insects.

Notwithstanding the fact that the so-called "wild" spawning of carp took place in the ponds, few fingerlings of the carp were caught in the autumn, as the bulk of them had been eaten by the trout.

5 CONCLUSIONS

The results described above show that trout can be a valuable addition in carp ponds even under conditions of multi-species stocking. It is particularly desirable to use the rainbow trout as a predator in a pond where uncontrolled spawning of carp may take place. The growing of a replenishment and foundation stock of trout on natural food in carp rearing ponds is of special interest, as it is often difficult to find good food for trout spawners.

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USE OF THERMAL WATERS FOR COMMERCIAL PRODUCTION OF CARPS IN FLOATS IN THE U.S.S.R.

by

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Abstract

The heated waters of power stations can be used for growing carp (*Cyprinus carpio*) in floats. Optimum temperatures for this range from 23 to 30°C.

In the U.S.S.R. vegetarian diets are used. Additions of 20 percent animal protein increase carp growth rates by 33 percent, but higher amounts are wasted (10-15 percent protein is sufficient).

Vitamins, given as 5 percent hydrolyzed yeast, increase growth rate of carp on vegetarian diets by 56 percent, and on mixed diets by 30 percent. The addition of 5,000 to 10,000 units of terramycin antibiotic per kg of feed stimulates growth by 10 to 17 percent, giving most marked results with vegetarian diets.

Experiments on rates of feeding showed that between 25 and 50 percent of body weight per day was the most effective; the efficiency of feed utilization was best at low stocking rates (stocking rates of 0.66 to 200 m^2 were tested).

Fish production in floats has risen to 100 kg/m^2. The growth rates of two-year-old fish stocked at 100, 200 and 250 m^2 are compared. Except in a cold summer, carp growth rates were generally lower in floats than in ponds. The flesh protein content of float-reared fish was higher than of pond-reared fish; haematological analysis showed the blood of carp fed on artificial foods to be normal.

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UTILISATION DE L'EAU DES CENTRALES THERMIQUES POUR LA PRODUCTION COMMERCIALE DE CARPES DANS DES PARCS FLOTTANTS EN U.R.S.S.

Résumé

Les eaux chauffées provenant des centrales électriques peuvent être utilisées pour l'élevage de carpes (Cyprinus carpio) dans des parcs flottants. Les températures optimales varient entre 23 et 30°C.

En U.R.S.S., les carpes reçoivent une alimentation végétarienne. En ajoutant 20 pour cent de protéines animales on a pu augmenter le taux de croissance de 33 pour cent, mais toute quantité supérieure est gaspillée (en fait, 10 à 15 pour cent de protéines suffisent).

Des vitamines, fournies sous forme de 5 pour cent de levure hydrolysée, provoquent une augmentation du taux de croissance atteignant 56 pour cent pour les carpes soumises à un régime végétarien et 30 pour cent pour celles bénéficiant d'un régime mixte. En ajoutant 5 000 à 10 000 unités d'antibiotique (terramycine) par kilo d'aliment on stimule la croissance de 10 à 17 pour cent, les résultats les plus nets étant obtenus avec les poissons recevant une alimentation végétale.

Des expériences portant sur le taux d'alimentation ont montré que l'on obtenait les meilleurs résultats en fournissant aux poissons une quantité d'aliments correspondant à 25 à 50 pour cent de leur poids; le meilleur taux de conversion alimentaire a été obtenu avec les plus faibles densités de peuplement (des essais ont été effectués avec des charges allant de 0,66 à $200/m^2$).

La production de poisson dans les parcs flottants a atteint 100 kg par m^2. Un tableau comparatif des taux de croissance de poissons de 2 ans chargés à 100, 200 et $250/m^2$ est donné. Sauf lorsque l'été est froid, les carpes élevées en parcs flottants accusent généralement un taux de croissance inférieur à celui des carpes élevées en étangs. La teneur en protéines de la chair des poissons élevés en parcs flottants est plus élevée que celle des poissons élevés en étangs; l'analyse hématologique n'a rien révélé d'anormal dans le sang des carpes soumises à une alimentation artificielle.

UTILIZACION DE AGUAS TERMALES PARA LA PRODUCCION COMERCIAL DE CARPAS EN CUBETAS FLOTANTES EN LA U.R.S.S.

Extracto

Las aguas calentadas de las centrales eléctricas pueden ser utilizadas para la cría de carpa (Cyprinus carpio) en cubetas flotantes. Las temperaturas óptimas para ello varían entre 23 y 30°C.

En la U.R.S.S. se utilizan dietas vegetarianas. La adición del 20 por ciento de proteina animal hace aumentar la tasa de desarrollo de la carpa en el 33 por ciento, mientras que el empleo de cantidades mayores es un gasto inútil (10-15 por ciento de proteína es suficiente).

Las vitaminas proporcionadas en forma de levadura hidrolizada al 5 por ciento aumentan la tasa de crecimiento de la carpa con dietas vegetarianas en el 56 por ciento, y con dietas mixtas en el 30 por ciento. La adición de 5.000 a 10.000 unidades de terramicina antibiótica por kg de alimento estimula el crecimiento en el 10 al 17 por ciento, dando los resultados más notables con dietas vegetarianas. Los experimentos sobre tasas de alimentación mostraron que una cantidad entre el 20 y el 50 por ciento del peso corporal por día era la más eficaz; el rendimiento de la utilización de alimentos fué óptimo cuando la densidad de repoblación era baja (se ensayaron densidades de 0,66 a $200/m^2$).

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La producción de peces en cubetas flotantes ha aumentado a 100 kg/m^2. Se comparan las tasas de crecimiento de peces de dos años con densidades de población de 100, 200 y 250/m^2. Excepto en un verano frío, la proporción de crecimiento de la carpa fué en general más baja en las cubetas flotantes que en los estanques. El contenido de proteína de la carne de pescado criado en cubetas flotantes fué mayor que el del criado en estanques; los análisis hematológicos evidenciaron que la sangre de la carpa alimentada con alimentos artificiales era normal.

1 RUSSIAN WORK ON CARP PRODUCTION IN FLOATS

Rearing carp in stews is one of the most important advances in fish culture of our time. The originator of this new method is a Japanese fish-culturist, Mr. Y. Tanaka (Kowamoto, 1957). Japanese fish culturists obtain fish yields of 150 to 200 kg/m^2 due to favourable climatic conditions and foods of high nutritive value (Lieder and Müller, 1965).

Ater Tanaka's investigations, work on rearing carp in stews (or floats) in the U.S.S.R. was intensified, but the technique adopted in the Soviet Union has been developed independently. It is worth mentioning that the first experiments with carp in stews were conducted by Prokulevich (1941) in 1940, earlier than those in Japan.

The yield of 150 kg of carps was obtained from a concrete tank of 300 m^2 and 0.9 m deep, the average individual weight of the carp being 600 g. Total feed supply included: cotton seed cake - 400 kg, dried mollusc meat - 70 kg, and rye bran - 25 kg. The forage ratio was 3.3. Many novelties were introduced in the technique of float fish culture by Mikheev (Mikheev and Meisner, 1962; 1965). He has developed special floats for spawning, fry nursing, rearing and wintering to meet the requirements of all age groups. These floats are characterized by constructional simplicity, but are limited above all, by the availability of running water. Floats are placed in a large water body like lake or reservoir. Water exchange is natural due to wind, currents, and the active movements of fish in the float.

2 FLOAT CULTURE AND WATER TEMPERATURE

Carp culture in floats is restricted to the extreme south of this country due to temperature conditions. For instance, the weight gain of carp in experimental capron floats in Batumi (Georgia) at the population density of 50 per m^2 was 30 kg/m^2 (Korneev, 1963; Korneev and Korneeva, 1963a). Even in the south of Georgia the period of optimum temperatures for carp growth is not longer than six months, whereas carp in Japan grows for eight or nine months. In Central Russia, where more than 80 percent of the growth of two-year-old carp occurs during three months (June-August), float carp culture with artificial feeding has not yet been successful (Girbanov, 1962).

To improve conditions for fish culture in floats in the central regions of the U.S.S.R. the use of thermal waters was suggested, beginning with power station cooling reservoirs (Korneev, 1965). Generally the temperature of the water discharged by power stations is 10-15°C higher than the temperature of neighbouring natural waters. The water temperature at some power stations even in winter is above 20°C. Thus, temperatures in these cooling reservoirs are close to those in natural waters of North Africa (Verigin,1962).

Experience shows that the optimum temperature for growth of carp in floats ranges from 23 to 30°C. At 22°C a decrease in growth rate is observed, and at 20°C growth just about ceases.

Higher temperatures, up to 33-34°C, do not cause death, although growth rate decreases to some extent (Korneev, 1964).

3 CARP FOOD IN FLOAT CULTURE

The carp foods used in float culture in the U.S.S.R. mostly consist of artificial mixtures, in contrast with the Japanese method which offers a basic diet of animal origin consisting of a considerable amount of live food (Lieder and Müller, 1965).

3.1 Vegetarian diets

The possibility of rearing two-year-old carp at population densities of 50 per m^2 on a completely vegetarian diet, balanced as to amino acids and enriched with vitamins of the B complex has been proved (Korneev, 1963; Korneev and Korneeva, 1963a,b).

The average weight of carp reared in the subtropical zone for six months was 750 g. Their diet was composed of sunflower seed-cake (35 percent), soyabean cake (35 percent), shorts (25 percent), and hydrolyzed yeast (5 percent). The usefulness of this diet was proved by rearing two-year-old carps on such a vegetarian diet.

3.2 Amount of protein needed

Animal products included in the diet of the carp reared in floats promote fish growth. Addition of meat and bone meal (20 percent) to the carp diet in the 1961 experiments in Batumi (Korneev, 1963) increased growth rate by 33 percent.

To determine the optimum content of animal protein in the carp diet in 1965 a number of diets with varying amounts of animal protein (5 percent, 15 percent and 50 percent) from different sources were tried. Fish (herring) meal was used as a source of protein in the first lot and blood meal (basically albumin) in the second lot. Experiments were conducted in duplicate in floats placed in the coolers of one of the thermal stations in the Moscow oblast.

Basic components of the diet were barley flour (45 percent, 80 percent or 90 percent depending on the content of animal products) and fodder yeast (5 percent). Increasing fish meal in the mixture from 5 percent to 50 percent resulted in a growth rate increase of 27 percent and a decrease of fodder ratio of 21 percent, from 7.5 to 5.9. An increase in content of blood meal (from 5 percent to 50 percent) speeded up the growth of the fish by 45 percent and led to a decrease in the fodder ratio of 31 percent (from 7.5 to 5.2).

Increase of animal products in the carp diet leads to a considerable waste of protein. The practice of rearing carps in floats on diets with more than 50 percent animal products needs to be changed.

Animal protein does not seem to be a limiting factor in float carp culture. A 10 to 15 percent content of animal products in the diet will be sufficient.

3.3 Vitamins

One of the most important factors which influences carp growth in floats is vitamins. It has been found that complex vitamins are the most important to fish. In our experiments hydrolyzed yeast (5 percent) was used as a source of those vitamins. Experiments in 1961 (Korneev, 1963) showed that without yeast carps reared in floats do not grow even on amino acid balanced diets composed of meat and bone meal (20 percent).

A very marked effect can be achieved by the addition of hydrolyzed yeast to the strictly vegetarian diet: in this case the rate of growth is 56 percent higher. Addition of hydrolyzed yeast to the diet including 20 percent meat and bonemeal, increases the growth rate by 30 percent.

The addition of a paste prepared from aquatic plants (up to 20 percent wet weight, above ration) was most effective with a strictly vegetarian diet (giving an increase in growth rate of 14 percent) whereas when added to the mixture including 20 percent meat and bone meal the increase was only 3 percent.

3.4 Use of antibiotics

The antibiotic terramycin (Oxytetracyclin, fodder lots) at a rate of 5,000 to 10,000 units per 1 kg of food is favourable for growth of carps reared in floats. The growth-stimulating action of this drug is 10 to 17 percent. Fodder terramycin gives the best results with strictly vegetarian diets (Korneeva, 1965a; 1965b).

3.5 Rate of feeding

Besides the quality of food the success of the float method of culture depends largely on the rate of feeding. Over-feeding leads to uneconomic use of foods and an increase in the amount of food needed for the production of fish flesh. At the optimum temperature (25°- 27°) the carp is capable of consuming daily an amount of food equal to its own weight, or even more. In this case food is badly digested and the food conversion ratio increases to 14.

To find out the most effective daily ration for the carps reared in floats a number of experiments were conducted in the cooling reservoir of a thermal power station in the Moscow oblast in 1965. The amount of food in each experiment was increased two-fold (12.5 percent, 25.0 percent, 50 percent, of the body weight at the start of the experiments). In one of the experiments fish were subjected to starvation, and in the second one they were fed intensively.

The experiments carried out in duplicate, from 6 July to 30 September 1965 showed that both fish growth and food conversion ratio depended on the amount of food supplied daily.

In the experiments without feeding, the average body weight decreased as much as 22 percent. By the end of the experiments the difference between the fish which was over-fed and the fish on low level of feeding in weight increment was 110 percent. The dependence of the relative efficiency of carp growth and food conversion is shown in the Table I.

Table I

Carp growth and food conversion at various levels of feeding in floats

Level of feeding and amount of food in percentage of body weight	Over-feeding	High level	Medium level	Low level
Relative efficiency of growth (percent)	100.0	98.0	56.0	39.0
Relative efficiency of food conversion ratio	100.0	74.0	68.0	50.0

The most effective rate of feeding lies between medium and high level. At low level of feeding, in spite of good conversion of food into flesh, the rate of growth is too low to obtain fish of the standard size at the end of the rearing season. An important means of improving the conversion rate is higher frequency of feeding. The experiments conducted in 1965 show that with the same amount of food the fish fed 12 times daily yields twice as much as the fish fed once daily.

4 STOCKING RATES

Carps in our experiments were always reared in metal or capron net floats supplied with free-flowing water. Rates of stocking ranged from 50 to 250 per m^2, or from 0.5 to 2.5 million per ha. Such high densities, unusual in ponds, present certain problems which have yet to be studied.

Studies were made in 1963 on the influence of stocking rate on growth of carp in floats placed in the thermal waters of a thermal station (Korneev, 1964; 1965). The following rates of stocking were studied during a five month period: 0.66, 5.3, 50, 100 and 200 per m^2. The rate of growth and efficiency of food utilization by the carp are assumed to be 100 percent). The results are presented in Table II.

Table II

Growth and efficiency of utilization of food at various rates of stocking of carps in floats

Rate of stocking m^2	0.66	5.3	50	100	200
Relative growth (percent)	100	85	87	85	78.5
Relative efficiency of food utilization	100	100	103.7	112.2	118

Decrease of fish growth at higher densities and an increase of food conversion ratio is explained by accumulation of metabolic products which are poisonous to fish. These products of high biological activity offer great difficulties when determined by chemical methods even when their biological effect is evident. Oxygen content in floats and outside is almost always the same. Only after August the oxygen content in the floats was 0.2-0.3 ml/l lower than in the surrounding water.

Fish production in floats has steadily increased as a result of improvements effected in culture techniques. From about 15 kg/m^2 in 1960, it rose to 30 kg/m^2 in 1961, 60 kg/m^2 in 1963, and 100 kg/m^2 in one of the experiments in 1965. As the depth of water in floats was generally about 1 m, the production can be expressed as per m^3.

As the results of experiments in 1965 are the most interesting, we may consider them in detail here. One of the purposes of these experiments was to determine the maximum rates of stocking for rearing two-year-old carp in the stagnant water of floats.

Rearing the carp at densities of 100, 200 and 250 per m^2 lasted from 12 June to 30 September 1965. Like all other experiments this one was carried out in duplicate in floats of 3 m^2. Weight of fish at the start was 30 g. They were fed during most of the season with the following mixture:

grain waste	30-40 percent
sunflower seed meal	15-20 percent
peanut meal	15-20 percent
flax seed meal	10 percent
silkworm pupae	15 percent
fodder yeast	5 percent

The food was mixed with duckweed paste, the dry weight of which was about 50 percent of the total weight of other dry ingredients.

The mean monthly water temperatures during the experiments were as follows: June - 26.9°C, July - 27.0°C, August - 21.6°C, September - 21.4°C. Fish growth in each series of the experiments is shown in Tables III and IV.

Table III

Carp growth at various rates of stocking in 1965

Rate of stocking per m^2	Average weight of fish										
	June		July			August			September		
	12	28	2	11	22	3	12	29	6	19	30
100	43.0	55	62	75	140	205	264	329	400	424	485
	41.0	56	65	78	126	205	270	370	401	426	470
200	33.0	53	57	75	106	163	200	230	338	359	386
	44.0	54	63	79	104	160	203	245	340	360	396
250	33.5	51	54	70	100	156	213	245	324	363	400
	44.0	59	61	73.	102	168	221	280	330	370	385

Table IV

Results of fish culture experiments in 1965 (average of two parallel experiments)

	Rate of stocking per m^2		
	100	200	250
Average weight at the start (g)	42.0	38.5	39.0
Average weight at the end (g)	477.0	391.0	392.5
Fish yield per 1 m^2 (kg)	48.0	78.5	98.1
Average individual gain (g)	435.0	352	353.5
Gain per 1 m^2 (kg)	44.1	69.0	90.5
Gain per 1 m^3 (kg)	40.2	62.8	82.2
Fodder ratio	6.5	5.4	5.8

5 COMPARISON OF FLOAT- AND POND-GROWN FISH

Usually the rate of growth in floats is lower than in ponds. In 1965 the cold summer affected carp growth in ponds, therefore the growth of fish in floats was relatively better. This was a convincing demonstration of the advantages of fish culture in thermal waters.

Analyses show that rearing on artificially prepared foods did not reduce the amino acid content of the fish or affect their food value. On the contrary, the amount of raw protein in the fish reared in floats is somewhat higher (17-19 percent) than in the carp reared in ponds (Korneeva and Korneev, 1965). Data on amino acid content of carp muscles show that these are close to those in carps reared on natural food (Sorvachev, 1959).

Haematological analysis did not reveal any abnormalities in the blood-forming system of the fish fed on artificial foods.

Young-of-the-year carp reared on artificial food mixtures maintain a good rate of growth, and reached a weight of 750-1200 g on the same diet during the next year (Korneev and Korneeva, 1963a). This and other investigations show that carps fed on artificial diets preserve their physiological normality and value for human consumption.

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TECHNIQUES OF REARING PHYTOPHAGOUS FISHES

by

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Abstract

The history of attempts to acclimatize and breed phytophagous carps from the Far East, the grass carp *Ctenopharyngodon idella*, the silver carp *Hypophthalmichthys molitrix*, and the bighead *Aristichthys nobilis*, are described.

The progeny of grass carp brought from the River Amur and silver carp brought as young from China, were first bred in the U.S.S.R. in 1961, and mass production of young was organized in 1963, the year that bighead were first bred in the U.S.S.R.

The only method of obtaining eggs of these fishes in the U.S.S.R., is at present by injections of pituitary extracts. The artificial reproduction techniques to induce spawning by hypophysial injections, and techniques of rearing eggs and young are described in detail.

TECHNIQUES D'ELEVAGE DES POISSONS PHYTOPHAGES

Résumé

L'auteur fait l'historique des essais d'acclimatisation et d'élevage de carpes phytophages en provenance d'Extrême-Orient: *Ctenopharyngodon idella*, *Hypophthalmichthys molitrix*, et *Aristichthys nobilis*.

C'est en 1961 que l'on a pour la première fois élevé en U.R.S.S. les descendants de *Ctenopharyngodon idella* provenant du fleuve Amour, et d'*Hypophthalmichthys molitrix* provenant de Chine. La production en grand d'alevins a été entreprise en 1963, année où a été entrepris pour la première fois dans le pays l'élevage d'*Aristichthys nobilis*.

Aujourd'hui, c'est uniquement par injection d'extraits hypophysaires que l'on obtient en U.R.S.S. les oeufs de ces espèces. La communication décrit en détail les techniques de reproduction artificielle, qui consistent à provoquer le frai par des injections d'extraits hypophysaires, ainsi que les techniques d'éclosion des oeufs et d'élevage des jeunes.

TECNICAS DE CRIA DE PECES FITOFAGOS

Extracto

Se hace historia de las tentativas de aclimatar y criar carpas fitófagas procedentes del Lejano Oriente como la carpa herbívora *Ctenopharyngodon idella*, la carpa plateada *Hypophthalmichthys molitrix* y la carpa de cabeza grande *Aristichthys nobilis*.

La descendencia de la carpa herbívora del río Amur y de la carpa plateada trasladadas en su fase juvenil de China, se cultivó por primera vez en la URSS en 1961, organizándose la producción en gran escala de ejemplares jóvenes en 1963, es decir, el ano en que se cultivó por primera vez la carpa de cabeza grande en la URSS.

El único método de obtener huevos de estos peces en la URSS es en la actualidad mediante inyecciones de extractos pituitarios. Se describen detalladamente las técnicas de reproducción artificial para provocar el desove por medio de inyecciones hipofisarias y las de cultivo de los huevos y ejemplares jóvenes.

1 INTRODUCTION

This paper describes the work aimed at the acclimatization and commercial rearing of phytophagous fishes in the U.S.S.R. which was started in the late nineteen thirties.

The species used were the important food fishes from the Far East and China, the grass carp Ctenopharyngodon idella, the silver carp Hypophthalmichthys molitrix and the bighead Aristichthys nobilis. These are all large rapidly growing species, the grass carp growing to 32 kg in the Amur and a much higher weight in China; the silver carp to 16 kg in the Amur and a somewhat higher weight in China; and the bighead, not found in the Amur but growing faster and attaining a higher weight than the silver carp in the water systems of China. Grass carp feed on higher aquatic vegetation, including reed shoots and large plants as well as softer vegetation, silver carp mainly on phytoplankton, and bighead partly on aquatic plants and partly on phytoplankton and zooplankton.

2 HISTORY OF ACCLIMATIZATION

The first attempts to acclimatize these fishes in pond farms in the European part of the U.S.S.R., in the thirties, were not successful due to lack of knowledge of the biology of the fish and difficulties in transporting them over the long distances. The war then interrupted the attempts. These were resumed only in 1949, after a thorough study had been made of the biofauna of the Amur, including the biology of the phytophagous fishes.

The use of more efficient transport (special live-fish carrying vans and planes) allowed large-scale introduction of young grass carp, silver carp and bighead, first from the Far East, starting in the middle fifties from China. All the three species were brought to different regions of European U.S.S.R., the Middle Asian and Transcaucasian Republics.

Large numbers of both young and old age groups of these species were released for acclimatization into many natural waters and water-storage lakes, such as the Volga delta, the Kuban system, the Kara-Kum canal, the Kuibyshev, Tsymlansk and Novosibirsk reservoirs.

The transportation of large quantities of these species enabled experiments to be started on raising them in fish farms in various parts of the country.

These experiments showed that grass carp, silver carp and bighead survive the winter easily, not only in the South but also in the central and north-western regions of the Russian Federation. Two-year-old silver carp attains a weight of 300 g in the fish farms of the Middle Belt, and 1 to 1.5 kg in the South. Grass carp and bighead attain as much as 400 to 600 g in the Middle Belt and 1 to 1.5 kg in the South. Three-year-old silver carp attains 800 to 1,000 g in the Middle Belt, and grass carp and bighead 1.2 to 1.5 kg, the weight of some individually being even higher. Bighead released into the Kuban estuaries at the age of five years attained as much as 15 to 16 kg.

By rearing phytophagous fishes together with carp, one can obtain, without feeding, an additional 0.4 to 0.6 t/ha of fish in the farms of the Middle Belt, and not less than an additional 0.6 to 1.0 t/ha in the South. This is due to the fuller utilization of the natural food resources of the ponds.

By feeding grass carp with ground vegetation and by intensive fertilizing, the productivity of the ponds can be increased up to 3.0 to 4.0 t/ha.

As the grass carp feeds on aquatic vegetation it could be used for biological control of aquatic weeds in water-cooling reservoirs of power stations and in irrigation reservoirs.

However, the large-scale culture of these species could not be based on imported young, and it was found essential to work out methods of reproduction for commercial rearing of these fish.

3 ATTEMPTS TO BREED PHYTOPHAGOUS FISHES

The rearing of grass carp, silver carp and bighead was hampered by the idea that pond-reared females do not mature and that for this running water would be necessary. Only at the end of the fifties was it found that the females of all three species can reach maturity in the usual carp rearing ponds, and can be used for breeding (Verigin, 1963; Konradt, 1961).

In spite of the sceptic attitude of many experts, a number of research institutions raised parent stocks of grass carp, silver carp and bighead, in order to organize their rearing in various regions of the country, in the Moscow region, the Krasnodar territory, the Ukraine and the Turkmen Republic (Aliev, 1963; Sukhoverkhov, 1963).

The progeny of grass carp brought from the Amur and of silver carp brought as young from China, were first bred in the U.S.S.R. in 1961 in the Turkmen Republic. The same year progeny were obtained from pond-reared grass carp in the Ukraine (Aliev, 1963; Prikhodko and Nasal, 1963). In 1962, in addition to the Turkmen and Ukrainian Republics, a considerable number of the young was produced in the Krasnodar territory (Vinogradov, et al., 1965).

The scope of the work aimed at producing young was hindered by lack of spawners, but the 1961-62 investigations enabled the mass production of young to be organized in 1963 when a considerable number of spawners were raised on some fish farms.

In 1963 attempts were made to work out methods of obtaining and hatching eggs and rearing young on a commercial scale, to determine the parameters necessary for designing hatcheries for these fishes and the optimal conditions for transporting the larvae and young fish.

At the "Goryachy kluch" fish hatchery, Krasnodar territory, in 1963, four million young fish of these herbivorous species were obtained. Here, for the first time in the U.S.S.R. bighead young were produced, also a viable hybrid progeny of grass carp and bighead.

The rearing techniques were mastered in 1964 and 1965 for commercial production, and now almost all the fish farms of the Northern Caucasus have begun poly-species carp culture.

4 ARTIFICIAL REPRODUCTION TECHNIQUES

Phytophagous fishes mature rather late. Females of the grass carp, silver carp and bighead reach maturity at the age of three or four years in the Turkmen Republic. In the Krasnodar territory they mature at the age of five years, in the Ukraine (the Kiev region) - at the age of eight to nine years and in the Moscow region at the age of 10 years. As a rule males mature a year earlier than females. However, the conditions of rearing the spawners in the majority of the above places were not absolutely favourable, which might delay the development of the reproductive system of the fish. It is possible that when more favourable conditions for rearing are created we shall be able to speed up the maturity of spawners.

Numerous attempts to obtain sexual products of the majority of anadromous and catadromous fishes by imitating natural conditions for reproduction gave no satisfactory results. Neither in the Soviet Union nor abroad were the attempts to imitate the natural conditions for reproduction of these phytophagous fishes successful. The only method of obtaining the eggs of grass carp, silver carp and bighead in fish farms at present is by hypophysial injections. Although the males of all the three species attain the "running" stage without injections, these are necessary to obtain large quantities of milt.

After the injection of pituitary extract females of the grass carp, silver carp and bighead, as well as those of many other rheophil fishes, ripen whether or not there are running water conditions, or there are males present. Water temperatures close to the spawning temperature and a favourable oxygen supply are, however, essential.

When treating females of phytophagous fishes, giving successive (double) injections considerably increases the proportion of ripe females. We recommend the following method for administering the pituitary extract. A preliminary injection of one-eighth to one-tenth the final dose is given 24 hours before the final one. Females weighing 6 to 8 kg receive in the final injection seven to eight units of the wild carp (sazan) pituitary extract (average weight of a unit being 2.5 to 3.0 mg), and one unit in the preliminary injection. Females weighing 10 to 12 kg get 10 to 12 units of the extract, while the dose of the preliminary injection is not increased.

The stimulating injection (2.5-3.0 mg) to males is given at the time when females get the final injection.

For injections acetonized pituitary extract of semi-mature sazan, prepared during the spawning period, is used.

At a temperature of 20-23°C females mature 10-12 hours after the final injection. Artificial fecundation of eggs made by the Russian "dry" method gives good results. Taking into consideration fecundation selectivity the milt of two or three males should be used for fertilization. The percentage of fecundated eggs is not usually lower than 90.

The Weiss apparatus is the most suitable one for the incubation of eggs of phytophagous fishes; its main deficiency when used for eggs of the grass carp, the silver carp and the bighead, is the insufficient capacity. Eggs of these fishes swell a good deal (the diameter of an unfertilized egg is 1.0-1.2 mm and when swollen it amounts to 5 or even more mm). A standard 8-litre Weiss apparatus can hold 50,000-60,000 eggs. For large-scale work a considerable number of this apparatus is needed. It would be advisable to increase the capacity of the apparatus to 30-50 litres.

The eggs develop very rapidly. At a water temperature of 23-25°C the hatching begins 30 to 32 hours after fertilization and at a temperature of 27 to 28°C the period of incubation decreases to 20 to 24 hours. The water current carries the free embryos which have hatched from the eggs out of the apparatus, and they concentrate in the receptacles installed in the discharging system.

From the receptacles the free embryos are directly transferred to nurseries made of caprone gauze, gauge N 18-20, where they are kept till they start feeding. This they do four to five days after fertilization at a water temperature of 23-25°C. The fingerlings that have started feeding are taken from the nurseries and released in rearing ponds.

When ponds are stocked with larvae that have started to feed, their survival under favourable rearing conditions is not less than 50 percent. When stocked with larvae that have not begun to feed the survival rate sharply declines.

Fingerlings that have started to feed can endure long-distance transportation in oxygen-filled polyethylene containers.

In 1964-65 the VNIIPRH experimental fish hatchery "Goryachy kluch" (Krasnodar territory) exported about 90 million larvae of grass carp, silver carp and bighead to various regions of the U.S.S.R., Poland, Czechoslovakia, Hungary and Bulgaria. The mortality during transport was generally negligible.

Artificial reproduction has made large-scale culture of these fishes possible. Within the next two or three years large stocks of these fishes will be built up in a number of regions of the Soviet Union, which will fully provide for the needs of the commercial fisheries for fingerlings for stocking ponds.

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INTENSIVE FORMS OF REARING FISH IN PONDS IN PEAT-HAGS

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INTENSIVE FORMS OF REARING FISH IN PONDS IN PEAT-HAGS

Abstract

Peat-hags can be turned into fish ponds at comparatively low cost. This paper describes experiments made in the Moscow region to use them for rearing and fattening two-year-old carp (*Cyprinus carpio*), and the treatments necessary to make the ponds productive.

Peat-hags have acid (pH 5.0-6.5) water poor in nutritive salts and natural food. Untreated, their productivity averaged 50 kg/ha when stocked with 340 specimens/ha one-year-old carp. With feeding, carp production was increased five or six times.

Liming and manuring the dry peat, followed by additions of ammonium nitrate, superphosphate and potassium salts to the water through the summer, increased production to 300 kg/ha. The addition of grass carp and silver carp further increased production by 127 kg/ha.

Such fertilizers are, however, expensive. Trials were therefore made to release the organic nitrogen bound in the peat (1.8 to 3.3 percent in dry peat) and make it available for plant growth. For this one of the new peat-mineral-ammoniac fertilizers (TMAU), recently developed for agricultural use, was tested for fish culture. TMAU is prepared by adding ammonia solution to peat and leaving the stacks to mature for 25 to 35 days.

Fertilization with TMAU tested against controls showed that food and fertilizer expenditures for rearing 100 kg fish were 16 percent less in TMAU fertilized ponds, and the fish productivity in these ponds was increased by at least 80 kg/ha.

Investigations are being continued into this method of releasing nutrients from peat for circulation in the ponds.

ESSAIS DE PISCICULTURE INTENSIVE DANS DES ETANGS DE TOURBIERES

Résumé

Les tourbières peuvent être transformées en étangs de pisciculture à relativement peu de frais. Cette communication décrit les expériences effectuées dans la région de Moscou en vue de les utiliser pour l'élevage et l'engraissement de carpes de 2 ans (*Cyprinus carpio*), ainsi que les traitements nécessaires pour accroitre la productivité des étangs.

L'eau des tourbières est acide (pH 5,0-6,5) et pauvre en sels nutritifs et en aliments naturels. Dans des eaux non traitées, on a enregistré une production moyenne de 50 kg/ha avec une densité d'empoissonnement de 340 carpes d'un an par ha. Avec une alimentation d'appoint, la production était cinq ou six fois supérieur.

En pratiquant le chaulage et la fumure de la tourbe sèche et en ajoutant à l'eau pendant l'été du nitrate d'ammonium, des super-phosphates et des sels de potassium, on a réussi à porter la production à 300 kg/ha. L'introduction d'autres variétés de carpes (grass carp et silver carp) a permis d'accroître encore la production de 127 kg/ha.

L'emploi de ces engrais est toutefois coûteux. On s'est donc efforcé de libérer l'azote organique contenu dans la tourbe (1,8 à 3,3 pour cent dans la tourbe sèche) pour le mettre à la disposition des plantes. Pour ce faire, on a effectué des essais avec l'un des nouveaux engrais tourbe-minéral-ammoniac (TMAU) récemment mis au point pour l'agriculture. Le TMAU est préparé en répandant une solution d'ammoniac sur des tas de tourbe que l'on laisse mûrir pendant 25 à 35 jours.

Des essais ont montré que les dépenses en nourriture et en engrais pour élever 100 kg de poissons étaient moins élevés de 16 pour cent dans les étangs fertilisés au TMAU que dans les étangs témoins; en outre, la productivité du poisson dans ces étangs a augmenté d'au moins 80 kg/ha.

Des études se poursuivent sur cette méthode de libérer les éléments nutritifs contenus dans la tourbe pour les rendre à la circulation dans l'eau des étangs.

FORMAS INTENSIVAS DE CRIA DE PECES EN TURBERAS

Extracto

Las turberas pueden ser transformadas en estanques piscícolas con un gasto relativamente reducido. En esta monografía se describen los experimentos realizados en la región de Moscú con el fin de utilizar aquéllas para el crecimiento y engorde de carpa (Cyprinus carpio) de dos años, así como los tratamientos necesarios para hacer productivos los estanques.

Las turberas contienen agua ácida (pH 5,0-6,5), pobre en sales nutritivas y en alimentos naturales. Sin ningún tratamiento, su productividad era de 50 kg/ha al poblarlas con 340 individuos/hectárea de carpas de un año. Con alimentación artificial, la producción de carpa aumentó al quíntuplo o al séxtuplo.

Mediante el revestimiento y estercolado de la turba seca, seguida de la adición al agua de nitrato amónico, superfosfato y sales potásicas durante el verano, aumentó la producción a 300 kg/ha. La adición de carpa herbívora y carpa plateada aumentó aún más la producción en 127 kg/ha.

Sin embargo, tales fertilizantes son costosos. Por tal razón, se hicieron pruebas para liberar el nitrógeno orgánico de constitución en la turba (1,8 a 3,3 por ciento en la turba seca) y poderlo utilizar para el desarrollo vegetal. Con este fin se ensayó para la piscicultura uno de los nuevos fertilizantes turba-mineral-amoníaco (TMAU), producido recientemente para fines agrícolas. El TMAU se prepara añadiendo solución amoniacal a la turba y dejando los montones que maduren durante 25 a 35 días.

La fertilización con TMAU ensayada en comparación con testigos mostró que los gastos por concepto de alimento artifical y fertilizantes para la cría de 1000 kg. de peces eran 16 por ciento menores en los estanques fertilizados con TMAU, y que la productividad íctica en estos estanques había aumentado al menos en 80kg/ha.

Se están continuando las investigaciones sobre este método de liberar nutrientes de la turba para su circulación en los estanques.

1 THE POSSIBILITIES OF USING PEAT-HAGS FOR FISH CULTURE

Peat-hags and peat-milling fields are important but so far hardly used reserves of pond pisciculture. Peat-hags are barren lands overgrown with bushes and bog vegetation and subject to secondary bogging-up. Only a negligible part of peat-milling fields has been used for agriculture till now. The dug-out pits are not used at all. A considerable part of peat-hags can be turned into fish ponds at a comparatively low cost.

Several attempts have been made abroad (Mizersky, 1963) as well as in the Soviet Union (Grimm, 1890; Arnold, 1905; Eleonsky, 1930; Sebentsov and Ginsburg, 1932; Martyshev, 1957) to use peateries for piscicultural purposes. It was planned to use peat areas for fattening one-year-old carp (Cyprinus carpio) by intensive methods of rearing. The experiments in fattening in the peat pits of riverhead peat bogs gave unsatisfactory results and experiments in water bodies of low lands were more successful. The bulk of the experiments were made in peat pits which were not sufficiently suited to fish culture and which were very small.

A great contribution to pond pisciculture in peat-hags was made by Martyshev, (1957), who was the first to raise the question of the adaptation of peat pits for full-scale pond fisheries. However, the problem of the winter stay of fish in peat pits and the prospects of intensive fish rearing remained unsolved up till recently.

The All-Russian Research Institute of Pond Fisheries (VNIIPRH) has since 1958 been making investigations on the use of peat-hags for pisciculture. The experiments were made at the 100 ha experimental base of the Institute situated in the Moscow region on typical low-lying marshy land where there is 18 to 22 percent peat decomposition. The system of ponds was partially located in hydro-peat pits and at dug-out milling fields.

2 AIMS OF THE INVESTIGATIONS

The investigations were concerned with: (i) the type and biotechniques of fish farming in peat-hags and (ii) methods of intensification for raising under-yearlings and two-year-old carp. In this paper most attention will be given to the latter. As to the former we consider it may be stated that the investigations made by the Institute during many years have proved it possible to use peat-hags for full scale pond fisheries (Brudustova, et al., 1962; Mints and Khairulina, 1962). As a result of the investigations the problem of the hibernation of fish of different ages in peat wintering ponds has been solved.

3 PHYSICAL, CHEMICAL AND BIOLOGICAL CONDITIONS IN PEAT-HAGS

The investigations have shown that the medium regime in water bodies of peat-hags is extremely peculiar and is not altogether suitable for the life of fish. It is characterized by acid and weakly acid reaction of the medium (pH 5.0-6.5), very high colarity (up to 300°) and water oxidizability (up to 100 mg/l O_2), low content of the main biogenous elements, and considerable daily fluctuations in the content of oxygen dissolved in the water. Such ponds are short of natural food for fish which causes their relatively low productivity. At the beginning of the exploitation of the peat fattening ponds their productivity averaged 50 kg/ha, the density of the stock rate of one-year-olds being 340/ha, the weight of two-year old specimens in autumn being 168 g.

The exploitation of vast peat areas for pond pisciculture may be economically expedient only if high yields can be obtained. In this connection it was first necessary to find out whether it was possible to apply in peat-hag ponds the feeding method as the most effective method of intensification. Experiments which were made over two years (1958-1959) have shown that the feeding method in peat ponds is efficient enough. As a result of this method the productivity of the ponds was increased 5-6 times, and the stocking density of one-year-old fish was brought up to 750/ha (Mints and Khairulina, 1961). However the chemical regime continued to be not very favourable. The natural food supply also was comparatively poor.

Table I

Results of rearing two-year-old carp in fertilized peat ponds with feeding
(average data)

Year	Density of stock (one-year-old fish per ha)	Mean weight of two-year-old fish (g)	Production (kg/ha)
1960	1,287	625	680
1961	2,280	595	1,030
1962	2,960	360	880
1963	3,000	450	1,190

4 AMELIORATION OF PEAT-HAGS

It was of primary importance to work out methods of improving the physico-chemical regime so that it would provide normal living conditions for the carp and contribute to the most intensive development of the natural food supply. The creation of a favourable physicochemical regime in peat ponds is a necessary pre-condition for other intensification measures, such as increasing the density of the stock and more effective feeding.

4.1 Fertilization by conventional means

One of the methods to improve the medium which has been used in the ponds since 1960 is the application of a complex of organo-mineral fertilizers (Mints, 1962; Khairulina, 1962). To neutralize the natural acidity of the peaty soil, the cuphole of the pond was first filled with water lime, at the rate of 0.5-1.0 t/ha, dispersed along the bottom. This rate was fixed according to the pH. To accelerate the mineralization of the peat mould was dispersed along the dry bottom at the rate of 0.1-0.3 t/ha. To enrich the water in nitrogen, phosphorus and potassium, every other five days during the summer period ammonium nitrate (0.4-0.5 t/ha for the whole period), superphosphate (0.2 t/ha) and potassium salt (50 kg/ha for the period) were introduced into the water. This considerably decreased the acidity of the pond water (pH rose to 6.7-7.2); the water became richer in the main nutrient salts, especially in nitrogen (which rose to 0.5-1.0 mg/l) and phosphorus (up to 0.3 mg/l P_2O_5). The improvement of the medium promoted an increase in the natural food supply. After the addition of the fertilizers the mass development of algae was observed, while before the application of the fertilizers algae especially protococcal algae were very scarce. A noticeable improvement occurred in zooplankton and benthos which in the long run contributed to natural fish production in the ponds. Thus in 1960 the productivity of the fertilized ponds approximated 200 kg/ha at the average weight of 664 g in autumn for a carp, the density of the stock being the same as it was in 1958, i.e. 340/ha. In 1961 in conditions of greater density (539/ha) fish production amounted to 300 kg/ha at the average weight of 620 g for a two-year-old-carp in autumn.

4.2 Other methods of increasing productivity

The addition of fertilizers is not enough to obtain a high productivity from the ponds. The improvement of the hydrochemical regime due to the fertilizers allowed the stocking rate to be increased, and feeding to be intensified to obtain a higher fish productivity from the ponds (Table 1). Thus fish culture in peat-hags should develop along the usual lines for pond fisheries in the direction of intensification, i.e. by fertilizing ponds and adopting the feeding method.

Up to 1964 the experiments were made in ponds of 10 ha each. In 1964 for the first time commercial fish were reared in an experimental production pond of 57.3 ha area. The fish production of this pond due to intensive measures (feeding and fertilizing) was 750 kg/ha and the food expenditure was 3.66 kg per kg of weight gain. Phytophagous fishes (one-year-old specimens of the grass carp, Ctenopharyngodon idella and the silver carp, Hypophthalmienthys molitrix) were raised along with the carp in the same pond for the first time in "peat" ponds.

The herbivorous fish accounted for an additional output of 127 kg/ha. The total fish production of the pond together with the phytophagous fish equalled 870 kg/ha and the food expenditures decreased by 15 percent.

4.3 The activation of peat nitrogen by ammonia treatment

Despite the positive results we think that the fertilization of peat ponds in future should be carried out not by the usual methods used in pond pisciculture, but by the activation of biogenes contained in peat and by the conversion of organic compounds hardly suitable for phytoplankton into actively assimilable forms. It is known that absolutely dry peat substance contains 1.8-3-3 percent of nitrogen. But this nitrogen is mainly contained

Table II

Chemical ingredients of peat-ammoniac fertilizer
(peat + ammonia solution - 0.6% ammonia nitrogen)

Ingredients	Just after preparation	After matuing period before the fertilizatio of ponds
Dissolved humic substances (cold extraction) in percent	0.8	0.53
Nitrates, mg/100 g of absolutely dry substance	7.6	120.0
Ammonia nitrogen, mg/100 g of absolutely dry substance (water extraction)	152.0	180.8
Ammonia nitrogen, mg/100 g of absolutely dry substance (salt extraction)	570.0	230.9
Phosphates (P_2O_5), mg/100 g of absolutely dry substance	32.1	30.5
pH (water extraction)	6.8	6.1

in stable organic compounds and is therefore unavailable for plants. That is why peat needs additional treatment to promote the activation of nitrogen contained in it. In agriculture when peat is used as a field fertilizer, manure, faeces, etc. are added to it. Recently peat has been treated with ammonia liquor. This results in bringing about a new organo-mineral fertilizer. There are several kinds of peat-mineral fertilizers. One of them is the peat-mineral-ammoniac fertilizer (TMAU), the main active ingredients of which are peat organic substance in the form of humic compounds and assimilable forms of nitrogen, phosphorus and potassium. The investigations of the Central Peat Bog Experimental Station have shown that the high efficiency of TMAU is a result of interaction between humic acids and ammonia which increases the stimulating effect and biological activity of peat (Abramov, 1957; Fatchikhbina et al., 1960). TMAU is widely used in agriculture. In piscicultura its possible effects were quite unknown.

In 1962 VNIIPRH began to study these effects (Mints and Khairulina, 1965). The experiments were made in rearing and fattening ponds. Ponds fertilized with mould, ammonium nitrate and superphosphate were used as control. The density of fish stock in the ponds fertilized with different fertilizers was the same. The feeding method was used in all the ponds. To prepare TMAU, peat millings (ligniherbaceous peat with the amount of decomposition equal to 25-30 percent and moisture content equal to 60-65 percent) was used. The rate of ammonia solution added to peat was 0.6-0.9 percent of ammonia nitrogen in absolutely dry peat substance. In addition 10 kg of superphosphate were added to each ton of peat. In cases where the ponds were sufficiently provided with phosphorus, the fertilizer was made up without superphosphate.

The treatment of peat with ammonia solution gives a highly concentrated organic fertilizer with a considerable content of assimilable nitrogen which is in great demand in conditions of peat ponds.

One ton TMAU stacks mature in 25 to 35 days. During the maturing period distinct chemical changes take place in the TMAU, i.e. the content of ammonia nitrogen and humic substances decreases, and the nitrate nitrogen and biological activity of the fertilizer increases (Table II). The maturing period of TMAU depends on air temperature, weather conditions, humidity of peat and initial content of mineral ingredients of the fertilizer.

We used a somewhat greater amount of ammonia solution for treating peat compared with the rate usually used in agriculture, i.e. in this case TMAU was more concentrated.

No potassium was added to TMAU in this case, while in agriculture a rather large amount of it is added to the fertilizer. The relation of the mineral components in TMAU was rated in such a way that nitrification developmemt should be intensive. The best result is achieved when the content of nitrite nitrogen is high and the amount of ammonia nitrogen and humic substances is comparatively small.

Mature fertilizer was dispersed along the bottom of the pond 10-15 days before filling the ponds with water, and then fertilizer was periodically added to the water. The rate of TMAU dispersed along the bottom was 5 t/ha; after fertilization the bottom was harrowed. The distribution of TMAU along the water surface was usually begun 35 to 40 days after the ponds were filled with water, when the effect of the fertilizer dispersed along the bottom was hardly felt. During the season the fertilizer was applied along the water surface at the rate of 5 to 7 t/ha. The total expenditure of ammonia solution in TMAU in terms of nitrogen during the season averaged 53 to 64 kg/ha, 10 to 15 kg/ha were applied along the bottom and the rest of the amount was dispersed along the water surface. The total seasonal nitrogen expenditure in the case of ammonium nitrate fertilization equalled 158 to 185 kg/ha.

5 RESULTS OF FERTILIZATION EXPERIMENTS

The results of the work carried out over two years are summarized below.

In the case of the fertilization of rearing and fattening ponds with peat-ammoniac fertilizers, the consumption of nitrogen per ha is 2.8 to 3.0 times less and the consumption of superphosphate 1.7 to 1.9 times less than in the case of fertilizing ponds with ammonium nitrate and superphosphate.

The application of TMAU by dispersing it along the bottom of ponds is very effective. It intensified biological activity in the peat bottom of the ponds, promoted the development of a useful soil microflora and enriched the soil in available nitrogen and phosphorus compounds.

The application of TMAU noticeably affected the chemical composition of the water. Despite the lesser expenditure of nitrogen and phosphorus the content of nutrient salts, i.e. nitrate and ammoniac nitrogen and soluble phosphoric acid, was not less in the water of experimental ponds than in the control ponds. The lesser expenditure of nitrogen and phosphorus in the case of the fertilization of ponds with TMAU, and the richness of the water in the main nutrient salts permits the assumption that the increase in their content was accounted for not only by the nitrogen and phosphorus added to the TMAU, but also by the activation of the TMAU peat, and perhaps, partially by the activation of the peat bottom of the ponds, and involving these nutrient elements, nitrogen in particular, in the general circulation of substances in the pond.

The active reaction of the medium in the experiments and control ponds was weakly acid with a trend to alkaline reaction (6.8 - 7.8). The oxygen regime in the experimental ponds fertilized with TMAU (peat-mineral-ammoniac fertilizer) was not worse than in the ponds fertilized with ammonium nitrate and superphosphate. Some increase or decrease in the content of oxygen dissolved in the water of the ponds fertilized by different methods were mostly conditioned by the development of phytoplankton.

The observations on the development of natural food supply in ponds showed that the application of the peat-mineral-ammoniac fertilizer positively affects both the development of primary products and zooplankton and benthos. Usually in ponds fertilized with TMAU one can observe the "florescence" of water which is caused by protococcal algae. The zooplankton and benthos fauna of these ponds are richer. The dispersion of TMAU along the pond bottom has especially favourable effects on the development of the bottom food supply.

Thus in the experimental ponds fertilized with TMAU, the conditions favourable for intensive development of natural food supply were created, which contributed to the production. Table III gives data on the rearing of two-year-old carp. This shows that fish production in the experimental ponds during two years was somewhat higher than in the control ponds, and the food expenditures were much lower.

The lesser expenditure of fertilizers in the case of TMAU fertilization, some rise in fish production of ponds, and drop in food expenditure, all contributed to a decrease in the commercial production costs. Calculations (according to the data obtained in 1963) have shown that food and fertilizer expenditures for rearing 100 kg of fish in the fattening ponds fertilized with TMAU were 16.2 percent less than in the ponds fertilized with ammonium nitrate. Similar data were also obtained in the rearing ponds.

Thus the application of the peat-mineral-ammoniac fertilizer (TMAU) for the fertilization of peat ponds allowed the reduction of expenditure on nitrogen mineral fertilizers 2.8-3.0 times, and the expenditure of phosphorus fertilizers 1.7-1.9 times, and at the same time increased the fish production of the ponds by not less than 80 kg per ha. TMAU is a cheap local fertilizer and in future can be widely used in pond pisciculture in peat-hags

The first experiments in the application of TMAU have given promising results. Investigations in this field will be continued and the results will be checked in production conditions. Further investigations will be aimed at increasing the biological activity of the peat bottom and utilizing the potential capacities of the peat's "biogenous treasury" in the circulation of substances.

Table III

Rearing of two-year-old carp by applying different methods of fertilization

Experiment	Fertilizers applied for the whole season kg/ha		Fish production kg/ha	Mean weight of a specimen g	Food expenditure per kg of increase in production kg	Fertilizer expenditure per kg of increase in production kg	
	Nitrogen	Phosphorus				Nitrogen	Phosphorus
1962							
Complex of organo-mineral fertilizers	180.0	27.2	885	357.9	4.40	0.20	0.036
TMAU (peat-mineral-ammoniac fertilizer)	64	14.2	1110	404.7	4.30	0.058	0.013
1963							
Complex of organo-mineral fertilizers	158	30.4	1190	446.9	4.50	0.13	0.026
TMAU	53.0	17.9	1270	461.4	3.95	0.042	0.014

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VIII/E-7

EXPERIMENTS ON REARING FISH IN SALT WATERS NEAR THE DEAD SEA, ISRAEL

by

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Abstract

Experiments in Israel have shown that mullet, *Mugil cephalus* and hybrids of *T. nilotica* x *T. aurea* can be cultured together with carp (*Cyprinus carpio*) in waters of salinity varying from 2,000 to 8,000 mg/l Cl. Such culture may have great economic significance in enabling salt marshes and waters in other regions to be exploited. Further experiments are planned.

ESSAIS DE PISCICULTURE DANS LES EAUX SALEES PRES DE LA MER MORTE, ISRAEL

Résumé

En Israël, des expériences ont prouvé que les mulets (*Mugil cephalus*) et des hybrides de *T. nilotica* x *T. aurea* peuvent être élevés ensemble avec des carpes (*Cyprinus carpio*) dans des eaux où la salinité varie entre 2 000 et 8 000 mg/l Cl. Cette technique est susceptible de présenter un intérêt économique considérable si elle permet d'exploiter les marécages et eaux salées dans d'autres régions. De nouvelles expériences sont prévues.

EXPERIMENTOS DE CRIA DE PECES EN AGUAS SALADAS CERCA DEL MAR MUERTO, ISRAEL

Extracto

Experimentos realizados en Israel han demostrado que la lisa *Mugil cephalus* y los híbridos de *T. nilotica* x *T. aurea* pueden ser cultivados junto con la carpa (*Cyprinus carpio*) en aguas con una salinidad que oscila entre 2.000 y 8.000 mg/l Cl. Este cultivo puede tener una gran importancia económica al permitir la explotación de marismas y aguas saladas en otras regiones. Se proyecta la realización de nuevos experimentos.

The cultivation of fresh-water fishes in Israel has till now been carried out in artificial ponds supplied with water of low chloride content (normally 300-400 mg/l Cl). Such fish ponds are located mainly in the northern, cultivated part of Israel, on land which is sorely needed for agricultural purposes. Understandably, the shortage of arable land and fresh water has been a serious deterrent to the further development of fish culture in Israel. There are, however, extensive salt-marsh and desert areas (with water salinities of 2,500-8,000 mg/l Cl) along the southern part of the Dead Sea and in the Negev desert which, although unfit for agricultural purposes, could possibly be suitable for fish culture.

An attempt was therefore made to use these regions for this purpose. The first problem was to select the most suitable species of fish for introduction. The main fish cultivated in fresh water fish ponds in Israel is the common carp (*Cyprinus carpio*). This species is known to have a low growth rate in salt water, and is accompanied occasionally by *Tialpia aurea* or by the euryhaline mullet, *Mugil cephalus*.

Preliminary investigations have shown that hybrids of two *Tilapia* species (*T. nilotica* x *T. aurea*) tolerate water of high saline content. They were found to behave normally in water from the vicinity of the Dead Sea with a salinity above 2,800 mg/l Cl and containing large amounts of sulphates and manganese ions.

During 1962-63, two artificial ponds were dug near the Dead Sea: 8,000 m^2 in area (pond A); the other, 7,000 m^2 (pond B). The two ponds were then stocked with: *Cyprinus carpio* weighing 40 g and 110 g; fully mature male *Tilapia aurea* and female *T. nilotica*; and 0.1 g *Mugil cephalus*. The salinity of water varied from 2,000 to 8,000 mg/l Cl. Experiments were carried out in each pond separately during two growth seasons as follows:

Pond A 23 December, 1962 - 21 June, 1963 (season a)
22 June, 1963 - 29 October, 1963 (" b)

Pond B 10 February, 1963 - 25 June, 1963 (" a)
30 June, 1963 - 16 October, 1963 (" b)

The growth rates and yields of fish per season are summarized in the following table:

Pond	Season	Fishes stocked	Number stocked	Weight per fish (g)	Growth per day (g)	Fish yield kg/ha season
A	a	Carp	162	40	1.72	120
		Mugil	1,000	0.1	0.30	500
		Tilapia	Breeding season			
A	b	Carp	100	110	0.77	10
		Mugil	188	50	2.32	561
		Tilapia	132	1	2.32	351
B	a	Carp	170	40	0.20	133
		Mugil	Not stocked			
		Tilapia	Breeding season			
B	b	Carp	157	110	0.87	-
		Mugil	171	50	2.77	512
		Tilapia	143	50	4.16	643

The results of this single year experiment, suggest that culturing of *Mugil cephalus* and *Tilapia* hybrids together, may be of great economic value, in that it enables exploitation of the numerous salt marshes and saline waters such as are found in the desert part of Israel and other arid regions of the world. During the coming years, further experiments are to be carried out in the southern part of Israel.

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VIII-IV/E-8

THE NAME AND NATURAL DISTRIBUTION OF THE "*TILAPIA* FROM ZANZIBAR" (PISCES, CICHLIDAE)

by

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Abstract

Two species of *Tilapia*, both African in origin, have been used at the Tropical Fish Culture Research Institute at Malacca for studies on breeding and growth. The first, *Tilapia mossambica* Peters, was found to have established itself in Java in 1939. Its natural home is in the eastern rivers of Africa from the Zambezi southwards. The second, imported to Malacca from Zanzibar, was probably introduced to that island and is specifically identical with the *Tilapia* of R. Wami on the African mainland opposite. It had no valid name until 1966 when the species was named *T. hornorum* Trewavas. This is the species whose male, mated with females of *T. mossambica* or of *T. nilotica* gave an all-male FI generation (Hickling, 1960; Pruginin in FAO/UN, 1965).

The main distinguishing characters of *T. mossambica*, *T. hornorum* and the related *T. urolepis* are tabulated.

NOM ET DISTRIBUTION NATURELLE DU *TILAPIA* DE ZANZIBAR (PISCES, CICHLIDAE)

Résumé

Deux espèces de *Tilapia*, toutes deux d'origine africaine, ont été utilisées à l'Institut de Recherche de Pisciculture Tropicale de Malacca pour des études de reproduction et de croissance. La première espèce, *Tilapia mossambica* Peters, était établie à Java en 1939. Elle est originaire des rivières qui coulent en Afrique de l'Est, à partir du Zambèze vers le Sud. La deuxième espèce, importée à Malacca de Zanzibar, a probablement été introduite dans cette île, et ne diffère pas de l'espèce de *Tilapia* de la rivière Wami, sur le continent Africain de l'autre côté du détroit. Elle n'avait pas de nom officiel jusqu'en 1966, époque à laquelle l'espèce a reçu celui de *T. hornorum* Trewavas. Il s'agit de l'espèce dont le mâle, accouplé à des femelles de *T. mossambica* ou de *T. nilotica* a donné une génération F1 composée entièrement de mâles (Hickling, 1960; Pruginin dans FAO/NU, 1965). Les caractéristiques distinctives de *T. mossambica*, de *T. hornorum* et de l'espèce apparentée *T. urolepis* sont indiquées sous forme de tableau.

NOMBRE Y DISTRIBUCION NATURAL DE LA *TILAPIA* DE ZANZIBAR (PISCES, CICHLIDAE)

Extracto

Para llevar a cabo estudios sobre cría y crecimiento se han empleado dos especies de *Tilapia*, ambas de origen africano, en el Instituto de Investigaciones de Piscicultura Tropical de Malacca. La primera, *Tilapia mossambica* Peters, se estableció en Java en 1939. Su habitat natural se encuentra en los ríos orientales de Africa desde el sur del río Zambeze. La segunda importada a Malacca desde Zanzibar fue probablemente introducida en esa isla y no se diferencia específicamente de la *Tilapia* del río Wami, en la parte frontera del continente africano. No tenía nombre válido hasta 1966 en que se le dió el de *T. hornorum* Trewavas. Se trata de una especie, cuyo macho, emparejado con hembras de *T. mossambica* o de *T. nilotica* produjo una generación F1 totalmente de machos (Hickling, 1960; Pruginin en FAO/UN, 1965). Se indican en un cuadro los caracteres distintivos de *T. mossambica*, *T. hornorum* y de la afín *T. urolepis*.

1 HISTORY OF TILAPIA INTRODUCTION IN MALACCA

At the Tropical Fish Culture Research Institute in Malacca two microphagous forms of the African genus Tilapia have for some years been the subject of experimental breeding and growth studies. These and the histories of their arrival at Malacca are as follows:

(i) Tilapia mossambica Peters. This is the now notorious species which was found to be present in Java in 1939 and by the end of the war of 1939 - 45 had become abundant in the fresh and brackish waters of that island. An African species, its mode of arrival in Java was unknown, but was assumed to have been by the agency of aquarium dealers, who might have shipped it from Beira or Durban. From Java it was taken by the Japanese to Malaya, and has since been distributed all over the tropical world, where it thrives and multiplies, often all too well (Atz, 1954; Chimits, 1955 and 1957).

Specimens from Java were sent to the British Museum (Natural History) in 1947 by Dr. J.D.F. Hardenberg and from Singapore in the same year by Mr. M.W.F. Tweedie (then Director of the Raffles Museum) and were determined by me as T. mossambica.

(ii) The Tilapia from Zanzibar. At some time in the 1950s Dr. C.F. Hickling decided to import to the Malacca Research Institute fresh material from Africa, and being in touch with the East African Marine Fisheries Research Organization at Zanzibar obtained his material from there. This population had been identified by me as a member of the "mossambica-group", but I had been uncertain of its status, whether a subspecies of T. mossambica or a related species (Talbot and Newell, 1957; Hickling, 1960). It became known in Malacca as "the African strain" or "the Tilapia from Zanzibar" in contrast to "the Malayan strain" or true T. mossambica. A Zanzibar male, mated with a female T. mossambica (Hickling, 1960) or T. nilotica (Pruginin in FAO/UN, 1965) produced an all-male F1 generation.

The more I learnt about the taxonomy of Tilapia the more I hesitated either to identify the Zanzibar population with a mainland species or to give it a separate name on the basis of preserved specimens.

Thanks to the sponsorship of the Ministry of Overseas Development in London, and to the cooperation of the governments and fisheries personnel of Uganda, Kenya, Tanzania, Zambia and Malawi, I was able in 1965 to see a number of populations of Tilapia in the field, among them some that were critical in reaching a decision about the Zanzibar fish.

Briefly, I concluded that T. mossambica Peters is confined to the Lower Zambezi and its tributaries and to eastward-flowing rivers and coastal lagoons southwards to Natal; and that the Tilapia of Zanzibar is closely related to that of the River Wami system on the opposite mainland and requires a new name.

It may be useful (as well as serving as an apologia for my earlier hesitancy) to give a brief account of the steps by which this decision was reached.

2 IDENTITY AND DISTRIBUTION OF TILAPIA SPP. OF EAST AFRICA

In 1937, in trying to work out the relationships of some fossil remains of Tilapia which I then assigned to T. nigra (Gunther), I concluded that T. mossambica had a wide distribution in the eastward-flowing rivers of Africa, from Somaliland to Natal. This was chiefly based on the view that T. spilurus (Gunther), described from eastern Kenya, was synonymous with T. mossambica, which it resembles in numerical characters, dentition and the hypertrophy of the jaws in the breeding males.

Information gradually came to hand, however, showing that the breeding male of T. mossambica is black, whereas that of T. spilurus is not. For some time it was difficult to rely on this information, because most of the male T. mossambica described were from ponds or aquaria and their origin was unknown; nobody had seen a black male Tilapia in Kenya, and the breeding colours of this population had not been described.

Then to the description of a male T. mossambica (under its synonym T. vorax) from Transvaal by Gilchrist and Thompson (1917, p.486) was added that of others by Duplessis and Groenewald (1953, p.37), which fixed the black male with white cheeks to the southern form; and finally Whitehead (1962, p.623) described the quite different colouring of the male "T. mossambica" (= T. spilurus) of Kenya.

Not only are T. mossambica and T. spilurus distinguished on the important isolating feature of male colouration, but they are separated geographically. Until recently the British Museum collections included few specimens of Tilapia from the eastern Rivers south of the Pangani in the country now called Tanzania, or from Zanzibar. Such as we had were mostly rather small, and they differed from T. mossambica and T. spilurus in having higher numbers of gill-rakers and dorsal fin-spines. Among them was a single specimen from the Lower Rufigi, larger than the rest (150 mm S.L.), which had been made the holotype of T. urolepis Norman, 1922, named for its densely scaled caudal fin.

In the Vienna Museum are four specimens collected by the brothers Adolf and Albin Horn and made syntypes of T. adolfi Steindachner, 1916, an invalid name (see below). Two of these are large, from R. Ulanga, a tributary of R. Rufigi, and have densely scaled tail-fins. The others are smaller, from the Wami system near Kilosa, and their caudals are not densely scaled. It seemed probable that the scaly-tailed specimens from the Ulanga were conspecific with the holotype of T. urolepis; and possible that the smooth-tailed specimens from Kilosa were younger members of the same species.

In recent years the British Museum received more specimens from Zanzibar, and in 1964 Dr. R.G. Bailey, Fishery Research Officer in Tanzania, brought samples from the Wami locality of "T. adolfi". Both the Zanzibar and the Wami samples included specimens as large as the holotype of T. urolepis and even larger, yet without heavily-scaled tails.

The questions to be answered in the field were:

(i) Is the holotype of T. urolepis typical of the population of the Lower Rufigi?

(ii) Is this population continuous with that of R. Ulanga and does it extend into other tributaries of the Rufigi?

(iii) In what other river systems of Tanzania is T. urolepis found?

(iv) Particularly, are the "T. adolfi" of the Wami system also assignable to T. urolepis? To answer this question one would need to know at what size in T. urolepis the caudal becomes densely scaled. Does the same thing occur in the Wami population, either at the same or at a different stage in development? How do the male breeding colours compare in the different populations?

(v) Which if any of these populations is conspecific with the Zanzibar Tilapia?

(vi) Is T. mossambica also present in Tanzania?

The answers to these questions, so far as we could find them, are as follows, in the same order:

(i) Lower Rufigi. During my stay in Tanzania Dr. Bailey and I visited the Lower Rufigi at Utete, a few miles downstream from Mpanganye, the former German post where the future holotype of T. urolepis was found preserved by Mr. A. Loveridge after the 1914-18 war. In a backwater and lagoons near Utete we found an abundance of T. urolepis, the caudal fin being stiffened by its scaly covering at least from a standard length (S.L.) of 140 mm (total 180 mm) upwards.

(ii) *Tributaries of R. Rufigi*. I examined in the Tanzanian Fisheries Department collection a *Tilapia* of S.L. 241 mm from R. Ulanga, the tributary of the Rufigi which yielded two of the syntypes of "*T. adolfi*". It agreed with *T. urolepis*. More specimens of this species were examined fresh at R. Kilombero, another large tributary of the Rufigi. Here our samples included none between fry caught in pools and streams and large ones, 190–350 mm S.L., landed by fishermen. The latter all had thickly scaled tail-fins and recently spent males were coloured as those of *T. urolepis* of the Lower Rufigi, dark olive grey with red upper half of caudal fin and upper margin of dorsal.

(iii) *R. Kingani (Ruvu)*. This river enters the sea at Bagamoyo, about 40 miles north of Dar es Salaam, opposite the south end of Zanzibar. At Kigongoni Ferry, above the mangrove zone of the river, *Tilapia* and other fresh-water fishes were being landed. Here a specimen of 126 mm S.L. had a flexible caudal fin, not heavily scaled; one of 170 mm had scales on the rays extending to near their ends, but less densely than in the 140 mm Rufigi fish; two of 190 and 207 mm respectively had the caudal rays thickly covered with scales to near the posterior margin. We concluded that this is also *T. urolepis*, although we saw no ripe males.

(iv) From the Wami, we saw specimens freshly fished from lakes drained by R. Myombo, tributary of the Mukondokwa, near Kilosa, and others from a pond and dam at Ilonga research centre; there was also a series from the Myombo lakes preserved by Dr. Bailey in 1964 and presented to the British Museum. Although these included three of S.L. over 200 mm, in none were the caudal rays densely scaled, although the rays were thinly coated in some for about four fifths of their length; the fin was quite flexible, as in the majority of species of *Tilapia*. The colour of recently spent ripe or ripening males is nearly black, with some silvery, or rather aluminium-coloured scales on operculum and flanks, and the upper half of the caudal fin is not pink, but either banded or black like the rest.

(v) In the populations of the Rufigi, Kingani and Wami and in the Zanzibar samples meristic characters (numbers of fin-rays, gill-rakers and scales) are alike, and so is the dentition of jaws and pharynx. The Zanzibar samples agree with the Wami *Tilapia* in having a black male and the caudal without a dense scaly covering, but the aluminium-coloured scales of Wami males have not been observed in the Zanzibar fish.

There is one characteristic of the Zanzibar *Tilapia* which has not so far been tested in the mainland populations, namely its wide salinity tolerance (Talbot and Newell, 1957). An attempt to reach the Wami mouth failed because of bad road conditions. It seemed clear, however, from our excursions into the Rufigi delta that *T. urolepis* was present at the level of the Ndundu Ferry, but that at Mohoro, just above the mangrove zone, it was not caught locally. The fresh fish at Mohoro market represented a typical estuarine fauna, with young of marine fishes (Carangidae, Mugilidae, Lethrinidae and *Chanos*) and marine prawns. At Kigongoni Ferry, on R. Kingani, the *T. urolepis* was landed with typical fresh-water fishes – *Clarias*, *Eutropius*, *Synodontis*, *Distichodus* and *Alestes* – as well as members of the marine fauna which penetrate farthest into fresh water – *Chanos* and a mugilid. We thus have no evidence that *T. urolepis* lives naturally in saline water.

I conclude that the Wami and Zanzibar *Tilapia* are conspecific and distinguishable from *T. urolepis*. Since the distinguishing characters appear to include the male breeding colours and possibly salinity tolerance, it is at least a good working hypothesis to regard the distinction as specific.

The name *Tilapia adolfi* Steindachner, 1916, is unavailable, being a homonym of *Tilapia adolfi* Steindachner, 1909, itself a synonym of *Simochromis diagramma* (Gunther, 1894), a species of Lake Tanganyika. The syntypes of *T. adolfi* Steindachner 1916, as explained above, represent two species, one of which is provided with a name, *T. urolepis*; the other, which includes the specimen from Kilosa figured by Steindachner (1916, pl.v), now made the lectotype, requires a new name and I have proposed for it *Tilapia hornorum* Trewavas (Trewavas, 1966), to give the brothers Horn a third chance to be commemorated within the genus. The male colouration of the Zanzibar population seems to be slightly different, lacking the silvery scales, but a more detailed report from the living fish is desirable. The first Tilapia to be received at the British Museum (Natural History) were presented in 1918 by Dr. W.M. Aders, and the Museum correspondence files contain evidence that he introduced it from the mainland.

The main distinguishing characters of T. mossambica, T. urolepis and T. hornorum are set out in Table I.

(vi) We found no T. mossambica in any of these rivers, and preserved specimens from the Ruvuma are neither T. mossambica nor T. urolepis. With the recognition of T. spilurus of the Kenya rivers as a distinct species it is no longer logical to regard T. m. korogwe Lowe of R. Pangani, as a subspecies of T. mossambica. Its relationships are better expressed by giving it specific rank as T. korogwe.

I was able to see living specimens of a population of the true T. mossambica in the Lower Shiré River, tributary of the Lower Zambezi. In a lagoon near Chikwawa a small seine catch included a number of spent males retaining the breeding livery of intense black, with the lower part of the cheek white and with red margins of dorsal and caudal fins, as described and figured by Baerends and Baerends van Roon (1950, Figs 9, 22, 28-33, 47-52, under its synonym T. natalensis) and Neil (1964).

3 COMPARISON OF THE WILD FISHES WITH THE TWO SPECIES IN THE MALACCA PONDS

In the report for 1963 of the Tropical Fish Culture Research Institute in Malacca (p.17) a comparison is made between samples of the two parent species in Malacca and the hybrids in numbers of gill-rakers. In 10 T. mossambica the range is 14-16 (14 in 1, 15 in 5, 16 in 4), while in 50 from Zanzibar the range is 21-23 (21 in 13, 22 in 35, 23 in 4). Thus there is a gap between the two, and this is filled by a sample of 85 hybrids in which the count is 17-20 (mode 18).

As can be seen from Table I the ranges are wider and overlap in the African wild samples, with 19 - a number not uncommon in both. Moreover, in the following specimens of T. mossambica from Java, Malaya and Singapore the range is wider even for migrant T. mossambica:

7, 78-140 mm S.L., from Java (1947)

6, 37-167 mm S.L., from Singapore (1947)

1, 283 mm S.L., from Malaya (1948)

6, 127-152 mm S.L., from Malacca ponds.

These give 14 in 2, 15 in 3, 16 in 8, 17 in 1, 18 in 4 and 19 in 1.(Hybrids examined by me have 17-21).

The same samples of T. mossambica agree with the wild samples in having XV or XVI dorsal spines.

Colours of breeding males as described by Hickling (1960) for the Malacca parent species do not correspond so well with those described above, but the descriptions of peak breeding colours of T. mossambica in Java by Vaas and Hofstede (1952), and by Neil (1964) for specimens in California, derived from Malaya via Hawaii, agree well with my observations at the Lower Shiré. Hickling describes a mottled black and white male for T. mossambica, a pattern figured and described by Neil as a phase passed through on the way to dominant breeding livery. This pattern I have not seen (except in an aquarium fish of doubtful origin), but the wild males I saw were already spent.

The colour changes of the male T. hornorum from Zanzibar, both wild and in the ponds, still require full description. Meanwhile we can be confident that the original migrant to Java and Malaya was T. mossambica Peters, and the origin of the Zanzibar fish is sufficiently documented.

Table I

Distinguishing characters of three species of Tilapia
(N = number of specimens. Figures in brackets unique or very rare numbers)

	T. mossambica	T. urolepis	T. hornorum R. Wami	 Zanzibar
Dorsal spines No.	51	25	28	22
	XV or XVI(XVII)	XVI-XVIII	XVI-XVIII	
Total dorsal rays				
range	26-29	27-30	28-30	28-30
mode	28	29	29	29
mean	27.7	29.12	28.8	29.18
Gill-raker count No.	77	21	28	20
range	(14)16-19(20)	20-25(27)	(18)19-24(26)	19-23
mode	17-18	22-25 1/	22	20
mean	17.57	23.43	21.4	20.85
Colour of breeding male:				
general	black	dark olive	black, some silver marks	black
cheek	grey to white	dark olive	black	black
upper edge of D	red	red	red	red
caudal	black with red corners or margin	upper half pink, lower dark grey	?	dark with narrow red margin
Caudal scales	at base and part way along upper and lower	densely covering rays in adult	as T. mossambica a thin coating only	
Distribution	Lower Zambezi and southwards in eastern rivers and estuaries	Rufigi and Kingani	Wami system	Zanzibar

1/ 18 of the 21 specimens are in this modal class: 5 have 22 rakers, 3 have 23, 5 have 24 and 5 have 25.

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EXPERIMENTS IN THE CULTURE OF THE GREY MULLET, MUGIL CEPHALUS IN BRACKISH-WATER PONDS IN THE U.A.R.

by

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Abstract

Experiments were conducted in the culture of the grey mullet (*Mugil cephalus*) in the brackish-water ponds of the Mex Fish Farm in the U.A.R. The ponds were stocked with fry of about 22 mm length at the rate of two fry per m^3 of water. Selected ponds were fertilized with organic or inorganic fertilizers with necessary controls. Physico-chemical, as well as biological characteristics of the ponds were studied.

The highest yield obtained was 350 kg/ha in a pond fertilized with inorganic fertilizers as compared with 131.3 kg/ha in the control pond. With the extraneous fishes that gained access to the ponds, the maximum production obtained was 521 kg/ha. The survival rate of *Mugil cephalus* appears to be lower than that of *M. capito*. The growth rate of the mullet varied considerably between ponds. The possible factors that have affected the growth rate are discussed. It is pointed out that the Mex Fish Farm is not considered a productive farm and is normally used only for storage of fry for transplantation.

VIII/E-9

EXPERIENCES D'ELEVAGE DU MULET GRIS, MUGIL CEPHALUS DANS LES ETANGS A EAU SAUMATRE DE LA R.A.U.

Résumé

Des expériences d'élevage du mulet gris (Mugil cephalus) ont été effectuées en Egypte dans les étangs d'eau saumâtre de la Mex Fish Farm. On a procédé à l'empoissonnement avec des alevins d'environ 22 mm de longueur, à raison de deux alevins par mètre cube d'eau. Les étangs choisis ont été fertilisés avec des engrais organiques ou inorganiques, et les vérification nécessaires effectuées. On a étudie les caractéristiques physico-chimiques aussi bien que biologiques des étangs.

Le rendement le plus élevé obtenu a été de 350 kg/ha dans un étang fertilisé aved des engrais inorganiques, contre 131,3 kg/ha dans l'étang témoin. Compte tenu des poissons étrangers qui ont pu pénétrer dans les étangs, la production maximum obtenue a été de 521 kg/ha. Le taux de survie de Mugil cephalus paraît être plus faible que celui de M. capito. Le taux de croissance des mulets a varié considérablement selon les étangs. La communication examine les facteurs qui ont pu influer sur ce taux de croissance. Il est signalé que la Mex Fish Farm n'est pas considérée comme une exploitation productive et, en général, n'est utilisée que pour le stockage des alevins destinés au repeuplement.

EXPERIMENTOS DE CULTIVO DE LA LISA, (MUGIL CEPHALUS) EN ESTANQUES DE AGUAS SALOBRES DE LA R.A.U.

Extracto

Se realizaron experimentos de cultivo de la lisa (Mugil cephalus) en los estanques de aguas salobres de la Granja Piscícola Mex en la R.A.U. Los estanques se poblaron con jaramugos de unos 22 mm de longitud a razón de dos jaramugos por metro cúbico de agua. Se abonaron algunos estanques con fertilizantes orgánicos o inorgánicos con los estanques testigo necesarios. Se estudiaron las características físico-químicas, así como biológicas, de los estanques.

El rendimiento más elevado obtenido fué de 350 kg/ha en un estanque abonado con fertilizantes inorgánicos, en comparación con 131,3 kg/ha en el estanque testigo. Contando los peces extraños que entraron en los estanques, la producción máxima lograda fué de 521 kg/ha. La tasa de supervivencia de Mugil cephalus es inferior, al parecer, a la de M. capito. El ritmo de crecimiento de la lisa varió considerablemente de un estanque a otro. Se examinan los posibles factores que pueden haber influído en el ritmo de crecimiento. Se hace observar que la Granja Piscícola Mex no se considera una granja productiva y que normalmente se usa tan solo para conservar jaramugos destinados a ser transplantados.

1 INTRODUCTION

Experimental fish farms have been established in different regions of Egypt with the purpose of introducing fish culture in fresh- and brackish-water ponds. An experimental project in brackish-water pond culture was initiated at the Mex Fish Farm along the northern shore of Lake Mariut, close to the Mex pump station (Fig 1).

The grey mullet (Mugil cephalus) was chosen for such an experiment because of its importance in lagoon and estuarine fisheries in Egypt. Besides, their fry are always available in large quantities near the lake-sea connections where they are attracted by the brackish water of the Delta lakes (El-Zarka and Fahmy, 1967).

The experiment was designed to yield information on the productivity of the estuarine waters of the Mediterranean coast and the possible increase in their productivity through fertilization. The varying salinities of water in the experimental ponds make it possible to compare the rate of growth and condition of fish in waters of different salinities.

2 EXPERIMENTAL PONDS

Five ponds were chosen from the Mex fish farm for the experiment (Fig 1). They are rectangular having an area of 2700 to 6500 m^2 and shallow, the depth of water ranging between 80 and 170 cm depending on the bottom of the pond.

The water supply to the ponds is derived from the lake Mariut water discharge (salinity 1.7 - 2.5 g/l). To keep the water level of the lake at about 2.5 - 3.0 metres below sea-level, 2.0 - 3.8 million m^3 of water is pumped daily into the Mediterranean Sea. Each pond is provided with an inlet and an outlet pipe which are fitted with doors to keep the water level at the desired height and at the same time to prevent the entrance of undesired fish to the ponds.

The bottom of the ponds is of shelly limestone (shells of Cardium edule) covered with detrital materials. Calcareous tubes of tube worms were common in most of the ponds.

As for vegetation, Phragmites communis were present on the margins of the ponds and Potamogeton pectinatus and Najas armata were found in varying densities in the ponds themselves.

Table I

Stocking and treatment of different ponds in Mex Fish Farm

Pond	Water area m^2	Mean depth cm	No. of fry	Vegetation	Fertilizer
I	6,500	80	10,400	Phragmites on the margin only	PO_4 and NO_3; 20 kg of each/month
II	5,000	100	10,000	Heavy submerged Najas sp.	No treatment
III	3,625	80	5,800	Small patches of Potamogeton and Najas	NO_3 only 30 kg/month
IV	3,120	80	5,000	Patches of Potamogeton	Organic manure (cowdung) 30 kg/month
V	2,700	170	9,200	Heavy growth of Potamogeton	PO_4 only 30 kg/month

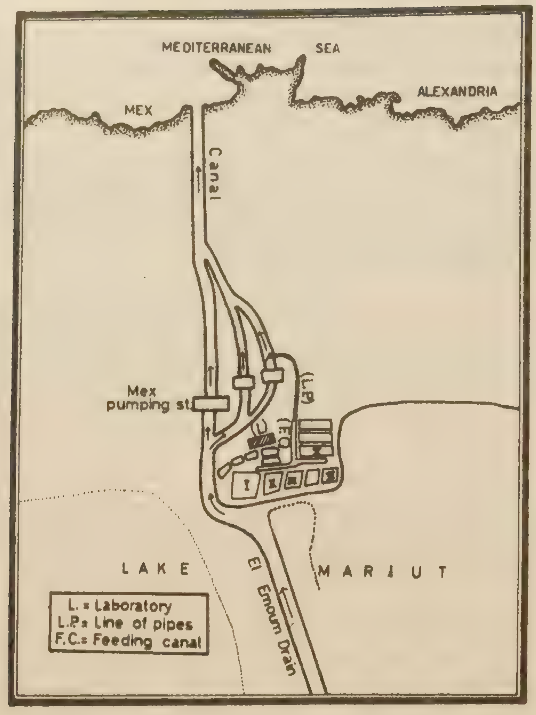
MEDITERRANEAN SEA
ALEXANDRIA
MEX
Canal
Mex pumping st.
L.P.
L.
F.C.
I
II
III
LAKE MARIUT
El Emoum Drain
L. = Laboratory
L.P.= Line of pipes
F.C.= Feeding canal

Fig. 1 Schematic drawing of Mex Fish Farm to show its position in relation to the Mediterranean Sea and Lake Mariut

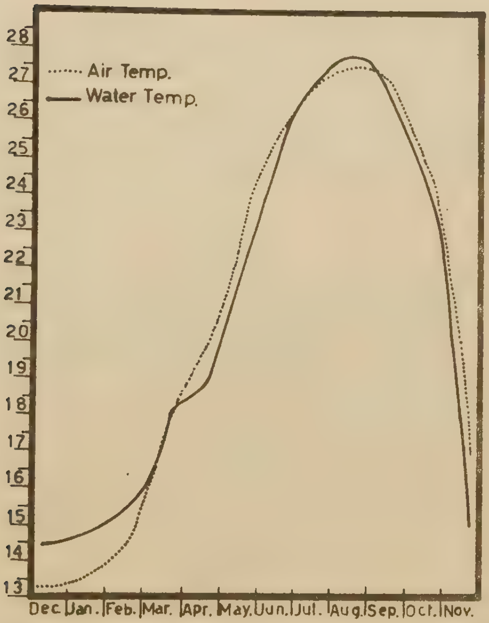

Fig. 2 Average water and air temperature in Mex Fish Farm

Periodic analyses of dissolved oxygen, chlorosity, pH, alkalinity, phosphate, nitrate and surface temperatures were made throughout the experiment. Phyteplankton samples were collected monthly and the dominant species were estimated qualitatively and quantitatively.

The physicochemical condition of the pond water during the experiment was favourable for the reared fish. The water temperature varied between a minimum of 14.4°C in December to a maximum of 27.8°C in August. Slight difference was observed between air and water temperature (Fig 2). The range in chlorosity was from 1.5 to 4.0 g/l. The low value of chlorosity during autumn was due to the Nile flood which usually affects the water discharge at that time of the year. The range in pH was from 8.4 to 9.0 and the highest value of pH was recorded in pond V during April and May. The alkalinity varied from 2.98 in May, to 6.54 milli-equivalent acid per litre in June. The dissolved oxygen attained maximum values of 9.92 and 8.16 ml O_2/l in ponds II and V respectively, during November. This might be due to the high photosynthetic activity of aquatic plants and to the low water temperature. On the other hand, a minimum value of 3 ml O_2/l was recorded in August. The phosphate and nitrate concentrations were affected to a large extent by the addition of fertilizers to the ponds (Table II and Fig 3). The maximum values of phosphate were reached in April and September when it was 3.58 and 8.00 microgram atom PO_4/l for the two months respectively. The sharp drop in the maximum concentration to 0.63 in May and 1.05 µg at PO_4/l in October might be explained as due to utilization of the phosphate ions by the existing phytoplankton blooms.

Table II

Concentrations of phosphates and nitrates in the ponds of Mex Fish Farm

	Phosphates : µg.at. PO_4 - P/l					Nitrates : µg.at. NO_3 - N/l				
	Pond I	Pond II	Pond III	Pond IV	Pond V	Pond I	Pond II	Pond III	Pond IV	Pond V
4 Dec. (1963)	1.05	0.80	0.80	0.80	1.67	0.10	0.07	0.10	0.18	0.07
15 Jan. (1964)	1.05	0.84	0.63	0.63	2.93	0.27	0.20	0.30	0.08	0.17
15 Feb.	0.93	0.83	0.52	0.43	3.36	0.10	0.05	0.20	0.07	0.14
18 March	0.84	0.42	0.42	2.10	5.00	0.07	0.04	0.10	0.14	0.14
19 April	2.51	0.72	0.63	1.26	5.44	0.07	0.05	0.07	0.04	0.05
20 May	0.64	0.41	0.52	1.05	1.46	0.30	0.28	0.81	0.41	0.17
20 June	1.05	0.84	0.72	0.84	1.88	0.52	0.19	0.80	0.55	0.29
25 July	0.84	0.52	0.52	1.05	1.67	0.35	0.14	0.28	0.14	0.10
19 Aug.	0.84	0.72	0.61	1.26	2.10	0.17	0.14	0.14	0.28	0.03
21 Sept.	3.58	2.10	2.52	3.36	8.00	0.05	0.00	0.17	0.02	0.00
19 Oct.	0.63	0.20	0.20	0.40	1.05	0.02	0.00	0.12	0.02	0.02
20 Nov.	1.78	0.20	0.20	0.72	4.40	0.00	0.00	0.14	0.00	0.00

The high values of phosphate in pond IV during summer was apparently due to the effect of high temperature on the added organic manures. Nitrate concentration did not follow the same trend as phosphate. The higher values of 0.52, 0.80 and 0.55 µg at.NO_3-N/l was recorded in the summer in ponds I, III and V respectively. The minimum values, on the other hand, were attained during spring and autumn.

As regards the biological characteristics of the ponds, the quantitative examination of plankton had shown that most of the algal groups were represented. Among the Myxophyceae, *Anacystis cyonea* and *Agmenellum* sp. were dominant during late autumn, while *Anabaenopsis circularis*, *Arthrospira plastenis* and most of the Oscillatoriaceae were abundant in late winter and spring. Members of the family Euglenaceae was dominant in winter. Family Chlorophyceae was represented by *Golenkinia radiata* which became dominant in autumn.

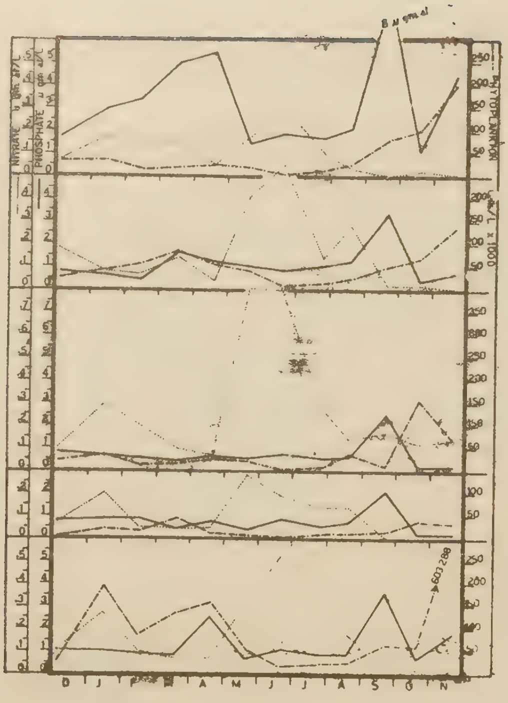

Fig. 3 Concentration of phosphate, nitrate and phytoplankton standing crop in the ponds of Mex Fish Farm

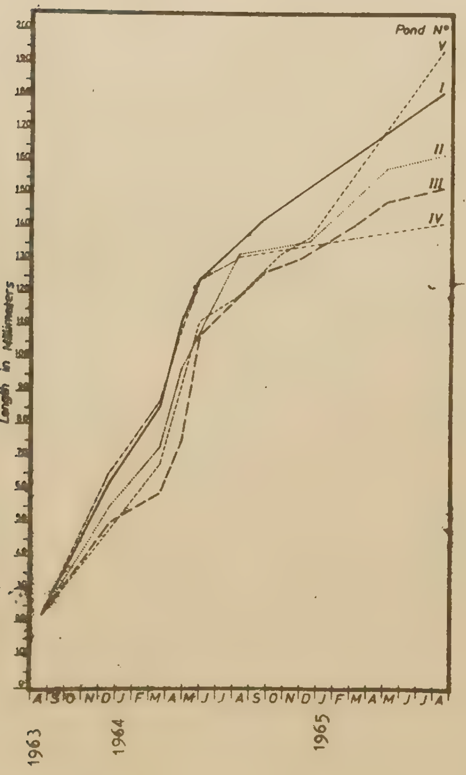

Fig. 4 Rate of growth of Mugil cephalus in the ponds of Mex Fish Farm

Ankistrodesmus falcatus and Scenedesmus sp. were observed to bloom during spring and autumn. Closterium sp. was abundant in winter and spring. Among the Bacillariophyceae, Cyclotella meneghiniana was present in the plankton all the year round with pronounced blooming in autumn and winter. Hyalodiscus species was found only during the summer. Melosira sp. was represented by few numbers in spring and autumn, and Cocconeis in spring only. Navicula and Pleurosigma spp. were detected in winter, spring and early summer. Other diatoms such as Amphiprora, Amphora, Rhopalodia, Bacillaria, Nitzschia and Campylodiscus were abundant in spring and autumn and present in small numbers in winter and summer.

The quantitative analysis of the phytoplankton indicated the effect of fertilization on the standing crop in the ponds. The average number of cells/litre was highest in pond I (119,666.9 cells/l), followed by pond V (57,867.4 cells/l), then Pond IV (50,466.5 cells/l), followed by pond III (33,910.6 cells/l). In the unfertilized pond II, the average number was only 16,637.7 cells/l (Table III). The variation in the magnitude of the phytoplankton crop in the fertilized ponds was due to the kind of fertilizer.

3 REARING EXPERIMENTS

On 18 August 1963, each pond was stocked with Mugil cephalus fry of 22 mm total length at a rate of two fry per m^3 of water. The number of fry in each pond is shown in Table I.

Ponds I, III and V were fertilized with commercial fertilizers: superphosphate and calcium ammonium nitrate either separately or in combination, at the rate of 20 to 30 kg of each per month. Pond IV was fertilized with an organic manure (cowdung) at the rate of 30 kg per month. For comparison, pond II was left without fertilization. Random periodical samples of fish were collected for biological studies. The ponds were drained on 15 August 1965 after a period of two years.

4 RESULTS

The total production of fish from the ponds after two years of growth had clearly shown the effect of fertilizers (Table IV). For the ponds which were treated with inorganic fertilizers (Ponds I, III and V), the highest yield obtained was about 350 kg/ha from pond V. For ponds I and III, the production was about 294 and 246 kg/ha respectively. In other words, the percentage increase in production due to fertilization varied from 166.7 kg for pond V to 116.6 kg for pond I to 87.6 kg for pond III. For pond IV where organic fertilizer was used, the mullet yield did not exceed 192 kg/ha showing an increase of 46.1 kg due to fertilization.

On the other hand, the mullet production from the unfertilized pond (pond II) was only 131.3 kg/ha which was fairly low in comparison with the fertilized ponds.

The ponds, when drained were found to contain other fishes such as Tilapia, Anguilla vulgaris, Synodontis schall and Chrysophrys auratus, in addition to Mugil cephalus. If the total weight of these fishes are included in the production estimate of the ponds, higher values of production were obtained; 521 kg/ha for pond V; 465 kg/ha for pond III; 445.8 kg/ha for pond I; 400.5 kg/ha for pond IV. For the unfertilized pond, the yield was 294 kg/ha.

In comparison with experiments on mullet culture in other parts of the world, the production we obtained cannot be considered very satisfactory. In the Philippines, the mullet production in ponds averaged 336 kg/ha (Carbine, 1948). At the Marine Research Laboratory in U.S.A., the production varied from 131.7 to 143.4 kg/ha for the fertilized ponds and 111.6 kg/ha for the unfertilized pond (Johnson, 1954). In Hong Kong on the other hand, a high value of 2508.8 kg/ha was claimed (Pillai, 1962).

Table III

The standing crop of phytoplankton (cells/litre) in the different ponds of Mex Fish Farm

Month	Pond I	Pond II	Pond III	Pond IV	Pond V
4 Dec. (1963)	25,346	4,725	22,575	25,368	28,926
15 Jan. (1964)	194,810	18,013	34,224	38,493	35,330
15 February	85,376	15,098	12,873	55,657	16,466
10 March	133,679	43,263	14,631	78,617	20,630
19 April	157,165	9,044	25,132	64,400	26,050
20 May	54,768	6,912	20,358	39,705	18,035
20 June	15,414	3,765	2,961	9,044	6,796
25 July	21,115	8,120	7,790	12,370	12,360
19 August	23,536	10,543	29,260	23,824	26,240
21 September	63,294	13,033	8,671	51,271	80,628
19 October	58,212	37,020	157,634	68,582	102,747
20 November	603,288	33,715	70,818	138,067	200,201
Mean	119,666.9	16,937.6	33,910.6	50,466.5	57,867.4

Table IV

Fish production in the Mex Fish Farm
(estimated after draining)

Production	Pond I	Pond II	Pond III	Pond IV	Pond V
Mullet					
Number of introduced fry............	10,400	10,000	5,800	5,000	9,200
Number of recovered mullet..........	3,406	1,663	2,806	2,312	1,556
Percentage mortality................	67.3	83.4	51.6	46.2	83.1
Weight in kilograms.................	176.0	62.5	85.0	57.0	90.0
Kilograms per hectare	284.3	131.3	246.3	191.8	350.0
Average total length (mm)...........	181.0	162.0	152.0	141.0	194.0
Average weight (g)	52.0	37.7	30.4	24.5	62.4
Percentage increase in production per acre due to fertilization.......	116.6	—	87.6	46.1	166.7
Total [1]					
Weight in kilogram..................	276.0	140.0	160.0	119.0	134.0
Kilograms per hectare...............	445.8	294.0	465.0	400.5	521.0
Percentage increase in production per acre due to fertilization.......	51.6	—	58.2	36.2	77.2

[1] other fish present were, Eels, Tilapia, Synodontis schall, Chrysophrys auratus.

The average size of mullets at the end of the experiment varied from pond to pond. The maximum average total length and weight were recorded from pond V (total length 194.0 mm average weight 62.4 g). Pond IV on the other hand gave the minimum values (length 141.0 mm weight 24.5 g). For the unfertilized pond, the average total length and weight were fairly high in comparison with the fertilized ones (total length 162.0 cm, weight 37.7 g).

Mortality reached the maximum of 83.4 and 83.1 percent in ponds II and V respectively. The least mortality was in pond IV, where it was 46.2 percent. The losses were 67.3 and 51.6 percent for ponds I and III. The high mortality among *Mugil cephalus* fry as compared with other mullet species has been observed in several transplantation experiments. In stocking an impoundment near Alexandria with mullet, it was found that 321 fry of *Mugil cephalus* were needed to produce one 0-group fish (length 22 cm). For *Mugil capito*, on the other hand, mortality was much less and three fry were needed to produce one 0-group fish (length 19 cm). The high mortality might have been due to the sensitivity of *Mugil cephalus* to handling and transportation, in addition to other environmental factors.

5 GROWTH CHARACTERISTICS OF *MUGIL CEPHALUS* IN THE PONDS

Periodical checking of the growth of the grey mullet has shown some variations in the different ponds (Fig 4). The growth rate was highest in pond I where the fish had attained a length of 142 mm and a weight of 26.2 g in 13 months. Comparatively high growth was reached in ponds II and IV where the lengths were 132 mm and 131 mm, and the weights 23.0 g and 21.1 g respectively for the two ponds. In ponds III and V the growth increment in 12 months did not exceed 97.0 mm, giving a total length of 119.0 mm and a weight of 15.9 g.

When the mullets stayed another year in the ponds, the growth characteristics showed a different trend. The growth was much improved in pond V, where the increments in length and weight were fairly high in comparison to the other ponds (75 mm, 46.6 g). Consequently, fish production from this pond was higher than from all other ponds.

In ponds II and IV, where the growth rate showed a good start after one year, a decrease in the rate was clearly observed during the second year of the experiment. The increment in growth dropped to 30 mm in pond II and to the lowest value of 10 mm in pond IV. The average total length and weight of fish were accordingly affected, reaching 141 mm, 24.5 g for pond IV, and 162 mm and 37.7 g for pond II.

The rate of growth of *Mugil cephalus* in the ponds is considered very low in comparison with those from coastal lakes and lagoons, especially during the second year of life. An average weight of 30.4 to 62.4 g were attained in the ponds after 24 months. The same average weights were reached after only one year in Nozha Hydrodrome and lake Edku.

5.1 Factors affecting growth

Several factors might have affected the rate of growth of *Mugil cephalus* in the ponds. Some of these factors might have a direct or indirect effect on the fish. Among the most significant factors, the following may be mentioned.

5.1.1. Temperature

The effect of temperature was observed during the early periods of stocking. The growth rate of fish in all ponds was not affected by the cold months. Growth attained its maximum value during the winter of 1963 and spring of 1964. From August 1964 to March 1965, the growth rate was at its minimum value.

Paget (1923) and Wimpenny (1934) showed that growth apparently begins when the mean temperature reaches about 20.0°C (March and November). This was also observed in our experiment especially during the second year of life (Fig 4).

5.1.2 Turbidity

The effect of turbidity on the growth of algae in the ponds was apparent. The transparency in the ponds varied from 10 to 30 cm, thus affecting the penetration of light to a certain extent. The effect of fertilization on the production of the ponds might also be masked by the turbidity of the water.

5.1.3 Nutrient salts

Fertilization had affected the productivity of the ponds to a varying degree depending on the kind of fertilizer. Although fertilization with phosphate or with phosphate and nitrate in ponds I and V gave the best results in the experiment, the production and the growth rate of fish were still not normal. This might be explained as due to the presence of shells at the bottom and consequently a high concentration of calcium in the water. Phosphorus may thus be easily lost through combination with calcium to form tricalcium phosphate (Bennet, 1962).

In pond III, where nitrate only was added, the productivity was comparatively low. The productivity could have been increased if phosphorus was added. Some algal forms are able to make use of nitrogen from the atmosphere if phosphorus is avaialble (Bennet 1962; Hickling 1962). This condition was well represented in pond III and pond I where the presence of phosphorus in addition to nitrate in pond I had given better production.

In pond IV, the treatment with organic fertilizer did not improve mullet production. It actually gave the lowest yield among the ponds (191.8 kg/ha). The ineffectiveness of the organic fertilizer was not felt when the fish was one year old. But during the second year, the pond seemed crowded and the carrying capacity of the pond did not favour the growth of fish. On the other hand, growth rate during the first year of life was not affected by the abundance of fry. The organic manure has been considered by many fish farming experts in Europe and Asia to be the best fertilizer of fry ponds (Hickling, 1962).

6 DISCUSSION AND CONCLUSION

The results of the Mugil cephalus rearing experiment has clearly shown that the treatment of Mex Fish Farm ponds with fertilizer did not improve the total yield to an encouraging level. The shell bottom of the ponds masked the effect of inorganic fertilizer. Moreover, the colloidal particles in the pond water absorb the nutrient salts, reducing their effect to a great extent. The rate of sedimentation was also recorded to be high, reaching about 0.6 mm per day. This certainly did not give a chance for the settlement of phytobenthic forms which serve as food for the grey mullet.

The phosphate fertilizer has been proved to be the most effective one among other fertilizers which were used in Mex Fish Farm. The fertilizer had increased mullet production at the end of the experiment by 166.7 percent.

The low production in the ponds might be due to the treatment of Mex ponds with various fertilizers (inorganic or organic) which might have encouraged the growth of several planktonic forms that were not suitable food for Mugil cephalus. Being a phytobenthic and epiphytic feeder, the grey mullet might not have found its normal food. Swingle (1947) indicated that inorganic fertilizers had encouraged the growth of the free-floating forms of algae which shades the bottom, thus preventing the growth of filamentous forms. To counteract such effect, he recommended the application of inorganic fertilizers while water is cold, thus giving the opportunity for filamentous algae to settle down on the bottom.

In conclusion it may be emphasized that the results of the experiment cannot be taken as a measure of the possible yield of mullet ponds in Egypt. The nature of Mex fish farm did not actually favour the culture of any fish species. It is mainly meant for the storage of mullet fry collected from the Mediterranean Sea. Lake Mariut in the neighbourhood of the Mex Farm is continuously stocked from the Mex farm.

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MALADIE DES POISSONS DANS LES ETANGS A TEMPERATURE ELEVEE EN EUROPE

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Résumé

Les maladies des poissons dans les étangs à température élevée sont en Europe assez répandues. Entre autres les maladies parasitaires et infectieuses présentent un problème sérieux. Les parasites les plus répandus sont les protozoaires qui infestent la peau et les branchies. La plus importante maladie infectieuse est la maladie virale Hydropisie infectieuse de la carpe.

Il est nécessaire de poursuivre et développer les travaux de recherches ayant pour objet le perfectionnement des méthodes de diagnostic, de prophylaxie et de traitement des maladies infectieuses et parasitaires. Il serait utile que, pour l'étude de ces maladies, un ou plusieurs centres soient formés qui seraient financés par les organisations européennes ou mondiales.

La lutte contre les maladies parasitaires et infectieuses doit faire l'objet d'une règlementation uniforme dans tous les pays.

IX/R-1

DISEASES OF WARM-WATER POND FISHES IN EUROPE

Abstract

In Europe fish raised in warm-water ponds suffer from many diseases, especially parasitic and infectious diseases. The most common ectoparasites are protozoa which live on the body and gills. The chief infection is the virus disease called infectious dropsy.

Research aimed at improving methods of diagnosing, preventing and curing infectious and parasitic diseases must be continued and extended. For this purpose one or more centres should be set up and financed by European or international organizations. Control of parasitic and infectious diseases should be ensured by standard regulations applicable in all countries.

ENFERMEDADES DE LOS PECES EN LOS ESTANQUES DE AGUA TEMPLADA EN EUROPA

Extracto

Las enfermedades de los peces en los estanques de agua templada se hallan en Europa bastante extendidas. Entre éstas, las enfermedades parasitarias e infecciosas presentan un grave problema. Los parásitos más extendidos son los protozoarios que infestan la piel y las branquias. La enfermedad infecciosa más importante es la enfermedad viral Hidropesía infecciosa de la carpa.

Es preciso proseguir y desarrollar los trabajos de investigación que tienen por objeto el prefeccionamiento de los métodos de diagnosis, profilaxis y tratamiento de las enfermedades, convendrá crear uno o más centros que podrían ser financiados por organizaciones europeas o mundiales.

La lucha contra las enfermedades parasitarias e infecciosas deberá ser objeto en todos los países de una reglamentación uniforme.

1 INTRODUCTION

Les maladies des poissons dans les étangs à température élevée, en Europe, commencent à se manifester plus fréquemment en relation avec l'intensification de l'élevage de la carpe (Cyprinus carpio). Vers la fin du siècle dernier et au début du XXe siècle déjà plusieurs rapports signalaient des maladies de poissons dans les étangs à température élevée. Une meilleure connaissance générale des maladies de poissons et surtout de celles des carpes en étangs, est due au Dr. Bruno Hofer, Professeur à la Faculté vétérinaire et Directeur de l'Institut biologique bavarois de Munich qui, en 1904, écrivit le premier "Traité sur les maladies de poissons". Son oeuvre fut continuée par sa collaboratrice, Professeur Marianne Plehn qui, en 1924, publia son "Practicum sur les maladies de poissons". Ces deux ouvrages nous donnent des renseignements fondamentaux sur les maladies de poissons, particulièrement en Europe occidentale, vers la fin du siècle dernier et au début de notre siècle.

Depuis lors, les maladies de poissons en Europe sont de plus en plus l'objet d'études. Les maladies de poissons en étang, à température élevée, sont surtout étudiées par des spécialistes de l'Europe centrale, orientale et méridionale où la cypriniculture en étang est très développée. Le nombre relativement grand des traités sur les maladies de poissons (25 environ) parus dans ces régions au cours des dernières décades témoigne de l'importance que présentent les maladies de poissons en Europe.

Les données utilisées pour la rédaction de ce compte-rendu ont été puisées dans les ouvrages mentionnés ci-dessus ainsi que dans de nombreux mémoires et travaux, de nombreuses communications personnelles, reçues de mes collègues de différentes parties de l'Europe auxquels j'adresse mes vifs remerciements.

Il est très difficile de passer en revue dans un laps de temps limité, toutes les maladies des poissons en Europe. J'ai donc décidé de présenter brièvement toutes les maladies importantes et d'indiquer les problèmes actuels pour les groupes particuliers des autres maladies. Afin d'éviter les malentendus, j'ai indiqué tous les noms des maladies et de leurs agents causals en latin.

2 PARASITES ET MALADIES PARASITAIRES

L'étude des parasites de poissons a commencé en Europe il y a bien longtemps. Certains parasites étaient déjà décrits au XVIIIe siècle. C'est de l'U.R.S.S. que provient la majeure partie des informations sur les parasites des poissons. Mille deux cent onze espèces de parasites sont décrites dans le livre "Le Diagnostic des parasites des poissons des eaux douces de l'U.R.S.S." (1962). Le plus grand mérite en revient à B.A. Dogelj (1882-1955), ses collaborateurs et successeurs qui travaillent au Laboratoire pour les maladies de poissons de l'Institut scientifique de la pisciculture à Léningrad. Mais nous avons également de nombreux travaux sur ce sujet provenant d'autres pays d'Europe et on peut généralement dire que les maladies parasitaires des poissons en étang à température élevée en Europe sont très répandues et présentent un problème sérieux.

La méthode d'élevage de la carpe favorise la dissémination de certaines espèces de parasites, en particulier ceux de la peau et des branchies ce qui explique la fréquence des maladies. Chez certaines autres espèces de parasites les méthodes habituelles d'élevage, telles que vidange, mise à sec et chaulage du fond, interrompent le cycle de leur développement, ce qui rend ces parasites plus rares dans les étangs et on n'en trouve en nombre important que dans les élevages où ces mesures ne sont pas ou ne peuvent pas être pratiquées.

Dans notre compte rendu nous nous bornerons à des parasites que l'on trouve assez fréquemment et qui déterminent dans la pisciculture en étang à température élevée des maladies et parfois même des pertes considérables.

2.1 Maladies causées par des protozoaires

Les plus répandus sont les protozoaires qui infestent la peau et les branchies des poissons. La densité de la population de poisson en étang permet une transmission facile de ces parasites d'un poisson à l'autre. Parmi les maladies déterminées par ces parasites la plus importante est l'ichthyophthiriasis.

La maladie est causée par *Ichthyophthirius multifiliis*. Dans les étangs il attaque surtout la carpe et la tanche (*Tinca tinca*), mais aussi d'autres espèces de poissons. Des infestations graves de la peau et des branchies s'observent à une température d'eau élevée et dans des élevages denses. Bien qu'il existe certains traitements qui détruisent le parasite sur le poisson même (vert de malachite, neguvon, etc.) les méthodes biologiques sont quand même plus avantageuses. L'essentiel est de transférer les poissons dans des étangs à densité réduite. Dans certains pays (l'U.R.S.S. et la République Démocratique Allemande et la Bulgarie) certaines mesures de lutte (déclaration obligatoire) sont réglementées.

Outre la maladie décrite on rencontre souvent dans les élevages de carpes certaines autres maladies protozoaires de la peau et des branchies. Les plus fréquentes sont les suivantes : Costiasis (agent causal : *Costia necatrix*), Chilodonellosis (agent causal : *Chilodonella cyprini*) et Trichodinosis (agent causal : *Trichodina domerguei*).

Ces parasites sont répandus dans tous les élevages d'Europe et on trouve des spécimens isolés sur des poissons parfaitement sains. Les poissons sont souvent infestés par plusieurs espèces en même temps. Toutefois, des infestations graves qui entrainent une maladie manifeste et même des pertes, n'apparaissent que chez des poissons jeunes et affaiblis dans des élevages à population très dense. L'application de bains et surtout la suppression des facteurs défavorables, mentionnés ci-dessus, combattent et préviennent efficacement la maladie. En Bulgarie, la quarantaine est prévue.

Dans les étangs à température élevée en Europe il y a également des parasites du genre *Glossatella* qui envahissent la peau des alevins. Toutefois, les manifestations morbides et les pertes sont rares et frappent plutôt des poissons affaiblis.

Une importance moindre revient aux protozoaires qui vivent en parasites dans le sang des poissons.

Dans les étangs à température élevée le Trypanoplasmosis attaque surtout la carpe (agents causals : *Trypanoplasma seu Crytobia cyprini* et *T. borelli*) et la tanche (agent causal : *Trypanoplasma tincae*). L'étendue de ces parasitoses n'est pas encore suffisamment connue, mais - des données recueillies jusqu'à présent - on peut conclure que cette maladie s'observe dans toutes les régions de l'Europe. Dans les étangs (surtout pendant l'hivernage) des pertes considérables peuvent se produire, en particulier chez la tanche.

Le Trypanosomosis (maladie du sommeil) est causé par de nombreuses espèces de parasites du genre *Trypanosoma* se trouvant dans le sang des poissons. La fréquence de ces parasites dans les étangs n'est pas assez connue. On a trouvé le *Trypanosoma danilewskyi* chez la carpe et le *Trypanosoma tincae* chez la tanche mais on n'a pas enregistré de pertes.

Les poissons peuvent être atteints par diverses espèces de coccidies dont les plus importantes dans les étangs à température élevée sont celles du genre *Eimeria*. La maladie peut se développer dans l'intestin de la carpe.

Le plus souvent, la *Coccidiosis cyprinorum* est causée par *Eimeria carpelli* (cyprini) (Coccidose à entérite). Des pertes importantes ont été observées chez l'alevin de la carpe mais cette maladie tend à se raréfier bien qu'elle soit encore assez répandue dans la partie méridionale de l'U.R.S.S. Moins importante est la Coccidiose à nodules, due à *E. epithelialis* qui produit des nodules inflammatoires dans la muqueuse intestinale de la carpe. Chez le tolstolobik (*Hypophthalmichthys molitrix*) on peut rencontrer le parasite *Eimeria sinensis*. La coccidiose peut être combattue avec succès par la mise à sec et le chaulage de l'étang.

En Europe les poissons sont souvent infestés par des protozoaires de la classe *Sporozoa*. Ils déterminent la formation des nodules dans différents organes. Ces affections peuvent avoir un nom commun : Sporozoosis tuberosa (maladie à nodules). Les agents causals les plus fréquents sont des sporozoaires des genres *Myxobolus* et *Henneguya*. Grâce aux mesures sanitaires la maladie n'est présente dans les étangs à température élevée qu'exceptionnellement. En Italie la déclaration de la Myxoboliasis est réglementée.

2.2 Maladies causées par des trématodes

Les poissons peuvent héberger de nombreux représentants de cette classe, soit à l'état adulte, soit à l'état larvaire. Toutefois, dans la pisciculture en étang à température élevée en Europe on n'en rencontre que très peu d'espèces. Parmi ces trématodoses la plus fréquente est l'infestation des branchies de la carpe.

Le Dactylogyrosis cyprinorum est causé le plus souvent par *Dactylogyrus vastator*. Ce parasite est répandu dans toute l'Europe. Il s'attaque à l'alevin de la carpe et peut lui infliger des pertes considérables. Les branchies de la carpe peuvent être siège aussi des autres espèces, telles que *D. extensus* (*solidus*) qui est également très répandue et qui cause de grandes pertes chez l'alevin, surtout en U.R.S.S.; puis *D. anchoratus* et *D. minutus* qui sont répandues et moins dangereuses. On lutte contre la maladie avec le plus de succès par les méthodes qui encouragent la croissance des alevins dans les premières semaines de la vie. Les bains ne présentent qu'une mesure complémentaire.

Dans les étangs on rencontre également l'infestation des branchies chez la tanche, appelée Dactylogurosis tincae . L'agent causal de cette maladie est *Dactylogyrus macracanthus* qui est répandu dans les étangs de toute l'Europe. On observe des pertes chez des tanches plutôt grandes qui sont affaiblies après l'hivernage alors que l'alevin semble épargné. Avec l'Amur blanc (*Ctenopharyngodon idella*) on a introduit dans la partie européenne de l'U.R.S.S. les *D. lamellatus* et *D. ctenopharyngodonis*.

Par contre, on observe moins de pertes dans les cas d'infestation cutanée: Gyrodactylosis. Celle-ci est due à plusieurs espèces du genre *Gyrodactylus*, le plus souvent *G. elegans* et *G. medius*. Ces parasites sont très répandus et peuvent être trouvés également sur des poissons parfaitement sains. On n'en trouve en grand nombre que sur des poissons affaiblis et sur ceux qui souffrent d'une autre maladie. Comme agents primaires des maladies de poissons ces parasites ne présentent pas une grande importance dans la pisciculture en étang. En Bulgarie la quarantaine est prévue pour les Dactylogyrosis et Gyrodactylosis.

Dans les étangs on rencontre très souvent une maladie causée par des trématodes digénétiques du genre *Sanguinicola* : Sanguinicolosis.

Sanguinicola inermis vit dans les vaisseaux sanguins de la carpe (moins souvent chez le carassin (*Carassius carassius*) et la tanche, *S. armata* dans ceux de la tanche et de la carpe, et *S. intermedia* dans ceux du carassin. Il n'y a pas suffisamment de données sur la distribution de ces parasites en Europe mais il est très probable qu'ils y soient répandus partout, y compris dans les régions occidentales de l'U.R.S.S. En cas d'infestation importante, les poissons succombent pendant la saison chaude, surtout les carpes âgées d'un an, moins souvent celles de deux ans. Chez la tanche et le carassin la maladie se manifeste très rarement. La mesure essentielle consiste en destruction des mollusques qui servent d'hôte intermédiaire pour ces parasites.

Diplostomosis: l'agent causal de cette parasitose est la cercaire du parasite *Diplostomum spathaceum*. A l'état adulte ce trématode vit dans l'intestin des oiseaux aquatiques. L'infestation sévère par ces cercaires chez les carpillons ou les jeunes tanches peut entraîner des pertes. Dans les étangs à température élevée en Europe ces infestations sont très rares. La lutte consiste en destruction des oiseaux aquatiques et mollusques.

Les métacercaires du parasite *Neodiplostomum cuticola* sont l'agent causal de la Neodiplostomosis (maladie des taches noires). Le ver adulte vit dans l'intestin des oiseaux aquatiques. Les métacercaires vivent dans la peau des poissons, surtout de la carpe. Ce parasite est très répandu en Europe. Des infestations importantes sont observées chez l'alevin de la carpe dans certains élevages en U.R.S.S. sans pertes cependant. Contre ce parasite on pratique avec succès la mise à sec de l'étang.

Dans les régions du Danube on rencontre chez des carpes en étangs une maladie dénommée Neascosis (maladie des petites granulations, "Perlkrankheit" en allemand). Cette maladie est causée par les métacercaires (que l'on appelle *Neascus perlatus*) du trématode *Neodiplostomum perlatum*. Le ver adulte vit dans l'intestin de divers oiseaux aquatiques. Les métacercaires se développent dans la peau, la musculature et certains organes de la carpe.

2.3 Maladies causées par des cestodes

Dans la pisciculture en étang à température élevée les maladies dues aux cestodes sont rares et sans danger.

Le Ligulosis est causé par le plérocercoide du cestode *Ligula intestinalis*. Le ver adulte vit dans l'intestin des oiseaux aquatiques et son plérocercoide dans la cavité abdominale de certains cyprinidés, surtout chez le genre *Abramis*, mais aussi chez la carpe et exceptionnellement chez les rapaces, le sandre (*Lucioperca sandra*) et le brochet (*Esox lucius*). Ce parasite est très répandu et on en trouve en nombre important également dans les étangs. Des pertes se produisent là où on n'applique pas les mesures sanitaires appropriées (mise à sec et chaulage du fond) et où il y a beaucoup d'oiseaux aquatiques.

Le Caryophyllosis est du aux parasites *Caryophyllus laticeps* et *C. fimbriceps*. Les vers vivent à l'état adulte dans l'intestin des poissons. Dans les étangs on les trouve chez des carpes et certains autres cyprinidés, surtout ceux du genre *Abramis*, mais aussi chez certains rapaces, le silure (*Silurus glanis*). Ce parasite n'a pas une grande importance et ce n'est qu'en cas d'infestations sévères qu'il peut causer des pertes, surtout chez des carpes d'un an.

Avec le *Ctenopharyngodon idella* de l'Asie, on a introduit dans la partie européenne de l'U.R.S.S. deux cestodes : *Bothriocephalus gowkongensis* et *Kavia sinensis* qui sont maintenant très répandus dans les étangs au sud de l'U.R.S.S. et y déterminent des pertes assez importantes chez la carpe et *Ctenopharyngodon idella*.

2.4 Maladies causées par les nématodes

De nombreuses espèces de nématodes peuvent infester, soit à l'état larvaire, soit à l'état adulte, différentes espèces de poissons de l'Europe. Bien qu'on en trouve également chez des cyprinidés, ces parasites n'ont, dans la pisciculture en étang, aucune importance. Il faut mentionner ici qu'on a introduit récemment dans la partie européenne de l'U.R.S.S. *Philometra lusii* qui habite sous les écailles de la carpe et cause des lésions inflammatoires.

2.5 Maladies causées par les acanthocéphales

Chez les poissons d'Europe les acanthocéphales sont assez répandus. Toutefois, dans la pisciculture en étang à température élevée, seul le *Neoechinorhynchus rutili* peut déterminer des manifestations morbides et même la mort de l'hôte en cas d'une infestation sévère dans l'intestin de la carpe.

2.6 Maladies causées par les hirudinées

Dans les étangs à température élevée d'Europe les sangsues Piscicola geometra et Hemiclepsis marginata sont très fréquentes, la première surtout sur des carpes adultes et la seconde plutôt sur l'alevin et les carpillons. Elles peuvent transmettre certaines maladies, telles que la trypanosomosis et l'hydropisie infectieuses de la carpe. Les sangsues Cystobranchus fasciatus - qui attaquent Silurus glanis - et C. respirans - qui attaquent le barbeau (Barbus barbus) et diverses autres espèces de poissons - n'ont, dans la pisciculture en étang, qu'une importance secondaire.

2.7 Maladies causées par les crustacés

Il y a relativement peu de parasites de la classe des crustacés qui infestent les poissons. Les plus importants font partie des genres Copepoda et Branchiura et quelques espèces seulement peuvent jouer un certain rôle comme agents causals de maladies dans les étangs.

L'Ergasilosis est du à deux espèces : Ergasilus sieboldi et E. briani (minor) qui siègent au niveau des branchies, surtout chez la tanche, chez laquelle ces parasites peuvent, dans les lacs ou les étangs, provoquer la maladie et même des pertes. Fréquentes sont les infestations dans les étangs alimentés par un lac. En République Démocratique Allemande la lutte contre E. sieboldi dans les étangs est réglementée.

Le Lerneosis est causé par Lernea cyprinacea. Ce parasite est trouvé dans de petits étangs. Il habite sur la peau du carassin, de la carpe et même sur celle d'autres poissons. On n'observe des pertes qu'en cas d'infestations très graves.

L'Argulosis est causé par des crustacés du genre Argulus que l'on trouve très fréquemment en Europe dans les étangs à carpe. Les plus fréquents sont A. foliaceus et A. japonicus (pellucidus). Ils s'attaquent surtout aux carpes et aux tanches. Ils se fixent sur la peau et sucent le sang du poisson. En cas de forte infestation leurs toxines peuvent nuire aux petits poissons. On considère qu'ils peuvent transmettre l'hydropisie infectieuse de la carpe. On lutte contre cette infestation par des bains de lindan, néguvon et autres. En Bulgarie la quarantaine est prévue pour cette maladie.

Avec Hypophthalmichthys molitrix on a introduit de l'Asie dans la partie européenne de l'U.R.S.S. le petit crustacé des branchies Sinergasilus major, dont le seul hôte est le poisson mentionné.

3 MALADIES INFECTIEUSES

3.1 Maladies à virus

L'une des plus importantes maladies infectieuses de la carpe est Ascites infectiosa cyprinorum (hydropisie infectieuse de la carpe). Elle est répandue dans tous les pays d'Europe où l'on pratique la cypriniculture en étang. Cette maladie peut affecter également mais à un degré moindre, certains autres poissons (tanche, carassin doré, Abramis sp., brochet, etc.) et on la rencontre assez souvent dans les eaux libres dont les poissons sont un facteur important dans la transmission de la maladie.

Cette maladie a été décrite plus en détail pour la première fois par W. Schäperclaus (1928). Il appert qu'elle existait déjà au XVIII^e siècle et les recherches de Schäperclaus ont grandement contribué à une meilleure connaissance de cette maladie.

Rarement l'étiologie d'une maladie fut davantage l'objet de discussions que l'hydropisie infectieuse de la carpe. Au cours des premières recherches on a observé que la maladie est due à Aeromonas (Pseudomonas) punctata et ces dernières années plusieurs auteurs ont prouvé en outre l'existence d'un virus dans cette maladie. La plus grande contribution dans ce sens fut fournie par G.D. Goncarov (U.R.S.S.). Donc, nous pouvons aujourd'hui considérer le virus comme l'agent primaire, et la bactérie A. punctata et quelques autres bactéries comme agents secondaires de cette maladie. Dans les dernières décades cette maladie a fait des ravages dans la cypriniculture en Europe. Toutefois, grâce à une meilleure connaissance de cette maladie et à l'application systématique des mesures appropriées on a déjà pu l'enrayer dans certains élevages et dans d'autres la réduire à un degré où elle ne représente plus un obstacle à la production de carpes en étangs. Dans la lutte contre cette maladie le meilleur effet fut obtenu par les mesures classiques de lutte contre les maladies infectieuses véritables. Pour le traitement et la prophylaxie on emploie avec avantage le chloramphenicol (chloronitrin), selon la recommandation de Schäperclaus. Dans certains pays européens on a pris des mesures obligatoires pour lutter contre cette maladie (U.R.S.S., Pologne, Allemagne d'Est, Bulgarie, Yougoslavie).

Epithelioma cyprinorum (variole de la carpe). C'est une des plus vieilles maladies de la carpe connue en Europe. K. Gessner (Suisse) la décrivait déjà en 1563. On la trouve dans les élevages de toute l'Europe, particulièrement chez la carpe,à un degré moindre chez la tanche et exceptionnellement chez d'autres cyprinidés. Toutefois, son étiologie était insuffisamment connue jusqu'à récemment. D'après les données les plus récentes c'est une maladie à virus (S. Roegner-Aust et B. Deubner ont démontré en 1953, au moyen du microscope électronique, des corps élémentaires, et L. Grützner a réussi, en 1956, à cultiver le virus sur la culture de tissu de poisson). Jusqu'à présent on n'a pas réussi expérimentalement à transmettre la maladie. Sur l'apparition de la maladie d'autres facteurs également exercent une influence considérable (carence en calcium et vitamines). Dans les élevages aux conditions impeccables la maladie n'existe plus ou bien se présente sporadiquement, sans causer de pertes importantes.

Maladies insuffisamment connues. Chez diverses espèces de poissons on rencontre assez fréquemment des maladies dont les symptômes principaux se manifestent au niveau de la peau (hémorragies, inflammation, nécrose de couches superficielles, ulcères). L'étiologie de ces maladies n'est pas encore suffisamment élucidée. Comme agents causals on incrimine des bactéries (principalement du genre Aeromonas) et certains autres facteurs. Toutefois, les données plus récentes, surtout celles de l'URSS, indiquent que des virus peuvent être, du moins dans certains cas, à l'origine de ces maladies. Peut-être s'agit-il ici du virus de l'hydropisie infectieuse de la carpe. Bien que nous ne connaissions pas suffisamment ce problème, de nombreux cas confirment déjà la plausibilité de cette conception. De nos jours on a déjà réussi à transmettre ces maladies de diverses espèces de poissons à la carpe et inversement, avec le matériel provenant des carpes atteintes d'hydropisie infectieuse, à transmettre la maladie au brochet et à certains autres cyprinidés. Les maladies infectieuses (contagieuses) des brochets et des tanches sont rares dans les étangs. Si, au cours d'une épidémie chez ces deux espèces, l'examen bactériologique s'avère négatif et les carpes du même étang souffrent d'hydropisie infectieuse, nous avons beaucoup de raisons de suspecter que chez ces deux premières espèces la maladie est également causée par le virus.

3.2 Maladies infectieuses bactériennes

Dans la littérature ancienne on trouve déjà la description de plusieurs maladies bactériennes qui affectent le poisson des eaux à température élevée en Europe. Ces maladies sont actuellement rares, certaines insuffisamment décrites et encore mal connues. Leurs agents causals seraient principalement des bactéries que l'on trouve partout dans l'eau.

Certaines de ces maladies étaient observées aussi dans les étangs. Parmi celles-ci on mentionne : Purpura cyprinorum (maladie rouge de la carpe), agent causal: Bacterium cyprinicida; Septicemia haemorrhagica tincae, agent causal : Bacterium septicemiae haemorrhagicae piscium; Inflamatio vesicae natatoriae cyprinorum, agent causal: A. punctata.

A noter qu'on n'a pas assez tenu compte de la relation éventuelle de ces maladies en étangs avec l'hydropisie infectieuse de la carpe.

3.3 Maladies causées par des champignons (mycoses)

Dans la cypriniculture en Europe une seule mycose présente un certain intérêt, et c'est : Branchiomycosis (pourriture des branchies).

Chez la carpe (et aussi chez la tanche) la maladie est causée par Branchiomyces sanguinis, et chez le brochet (et aussi chez la tanche) par B. demigrans. Selon les rapports de l'U.R.S.S. on a trouvé également, dans ce pays, d'autres champignons. Les champignons habitent les vaisseaux sanguins des branchies. La maladie est répandue dans toute l'Europe, mais sa fréquence varie considérablement d'un étang à l'autre. De nombreux étangs souffrent, presque chaque année, de grandes pertes tandis que dans d'autres la maladie est presque inconnue. Pour l'apparition de la maladie la présence de l'agent causal ne suffit pas (selon les données récentes ces champignons sont présents partout), il faut également d'autres facteurs (température élevée de l'eau, abondance en nourriture naturelle dans l'étang, substances organiques dans l'eau). Pour cette raison la lutte contre cette maladie est basée sur la suppression des facteurs la favorisant. Toutefois, l'enrayement de la maladie n'est pas praticable. En U.R.S.S. et en Bulgarie on exige la quarantaine des poissons malades.

Autres mycoses. Chez les poissons affaiblis ou malades et chez ceux ayant des lésions cutanées, des champignons (moisissures) aquatiques peuvent s'établir sur la peau et les yeux en agents secondaires. Ce sont surtout des membres de la famille Saprolegniaceae et Achlyaceae. On en trouve dans toutes les eaux.

3.4 Maladies causées par des algues

Ce n'est qu'exceptionnellement que des algues peuvent causer des maladies dans un étang. Une certaine importance est attribuée à Mucophilus cyprini qui peut s'installer au niveau des branchies et de l'épithélium de la peau de la carpe et même d'autres poissons. On l'a trouvée en Europe occidentale mais pas en U.R.S.S. Oodinium pillularis attaque la peau des alevins de la carpe, et peut provoquer des pertes considérables.

4 AUTRES MALADIES NON-INFECTIEUSES ET ORGANIQUES

On ne possède pas encore de documentation très précise en Europe dans ce domaine. En fonction de la présence de certains facteurs nuisibles ou de la carence de certaines substances dans l'eau ou dans la nourriture des manifestations morbides peuvent se produire. Dans la pisciculture en étang à température élevée on rencontre le plus souvent chez la carpe le rachitisme, l'osteomalacie et la perforation du couvercle des branchies. Le manque d'oxygène dans l'eau au cours de l'été est la cause fréquente des pertes. Les avitaminoses et les intoxications sont rares dans la cypriniculture. Pendant l'hivernage des pertes peuvent se produire chez les carpes sous la glace à cause de la composition défavorable de l'eau.

5 APERCU GENERAL

Généralement on peut dire que parallèlement à l'intensification de la pisciculture en étang à température élevée en Europe, le problème des maladies de poissons (infectieuses, parasitaires et autres) gagne en importance. Bien que la majeure partie de ces maladies soit déjà curable, l'état actuel des choses n'est pas satisfaisant.

Dans chaque pays où l'on pratique la pisciculture en étang il faudrait créer des institutions et des laboratoires qui s'occuperaient des questions concernant la recherche et l'application pratique des notions scientifiques, fournissant une assistance nécessaire dans la lutte contre ces maladies. Cette question n'est favorablement résolue que dans un petit nombre de pays européens.

En résumé, il y a des maladies qui représentent un problème important pour toute l'Europe et même pour une grande partie du monde. Il serait donc utile de créer un ou plusieurs centres qui recevraient les moyens financiers des organisations européennes ou mondiales, pour l'étude de ces maladies.

En même temps, nous pouvons rappeler que le transfert de poissons aux fins de repeuplement des eaux, d'une région à l'autre ou d'un pays à l'autre, et même d'un continent à un autre, favorise l'introduction de certaines maladies, par exemple, transmission de certains parasites en Europe par des poissons d'Etrême-Orient. Il est donc souhaitable que, dans le cadre international, certaines mesures soient mises en vigueur pour réglementer ces transferts, et nous ne pouvons qu'espérer que la recommandation du IIème Symposium (Munich, 1965) de la Commission Permanente de l'Office international des "Epizooties" pour l'étude des Maladies de poissons, porte ses fruits.

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IX/R-2

A REVIEW OF DISEASES AND PARASITES OF FISHES IN WARM-WATER PONDS IN THE NEAR EAST AND AFRICA

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Abstract

Diseases of fish become epidemics in warm-water fish ponds because of increased quantities of organic matter, stagnant water and crowded fish populations which facilitate the spread of disease-causing organisms.

The results of increased use of pesticides in agriculture would appear to point to the need for introduction of simple ways of controlling pests by spraying the whole pond area throughout the growing season of fish in fish culture. Factors which have to be considered in selecting new fish pesticides are discussed.

Three main groups of diseases affecting fish in ponds are described - endoparasites, ectoparasites and organisms which excrete toxic products into the pond water.

The possibility of identifying *Prymnesium parvum* toxin, extermination of this flagellate and blue-green algae and results of large-scale control of the ectoparasites *Argulus*, *Lernaea* and *Dactylogyrus* in Israeli fish ponds are described.

Records of ectoparasites in the inland waters of the Middle East and Africa reveal the occurrence of great reservoirs of potential infection of pond cultured fish. Precautional measures are proposed to prevent the hazards of parasitic infections and facilitate the large-scale development of fish culture.

MALADIES ET PARASITES DES POISSONS DANS LES ETANGS A TEMPERATURE ELEVEE AU MOYEN-ORIENT ET EN AFRIQUE

Résumé

Les maladies des poissons prennent un caractère épizootique dans les étangs de pisciculture à température élevée à cause des quantités accrues de matières organiques, de l'eau stagnante et de la densité de peuplement qui favorisent la prolifération des organismes responsables des maladies.

Les résultats obtenus en agriculture par un emploi massif de pesticides sembleraient indiquer qu'il y aurait lieu d'introduire en pisciculture des méthodes simples de lutte contre les ennemis des poissons, par exemple en effectuant des pulvérisations de pesticides sur la totalité de la surface de l'étang au cours de la période de croissance du poisson. L'auteur examine divers facteurs dont il y a lieu de tenir compte lorsque l'on choisit de nouveaux pesticides à usage piscicole.

La communication contient une description de trois principaux groupes de maladies auxquelles sont sujets les poissons en étangs : maladies à endoparasites, maladies à ectoparasites et maladies dues à des organismes qui sécrètent des produits toxiques dans l'eau.

Diverses questions sont étudiées : possibilité d'identifier la toxine de *Prymnesium parvum*, extermination de ce flagellé et des algues bleues et enfin résultats d'une lutte à grande échelle dans les étangs d'Israël contre les ectoparasites *Argulus*, *Lernaea* et *Dactylogyrus*.

Les renseignements dont on dispose concernant les ectoparasites dans les eaux intérieures du Moyen-Orient et de l'Afrique, font apparaître l'existence d'importants réservoirs d'infection potentielle des poissons élevés en étang. Des mesures préventives sont proposées pour éviter le danger des infections parasitaires et faciliter le développement massif de la pisciculture.

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EXAMEN DE LAS ENFERMEDADES Y PARASITOS DE LOS PECES EN LOS ESTANQUES DE AGUAS CALIDAS DEL MEDIO ORIENTE Y AFRICA

Extracto

Las enfermedades de los peces pasan a ser epidémicas en los estanques piscícolas de aguas cálidas dada la mayor cantidad de materia orgánica, el estancamiento del agua y la gran densidad de la población íctica que facilita la difusión de los organismos determinantes de la enfermedad.

Los resultados del mayor uso de los plaguicidas en la agricultura parecerían señalar hacia la necesidad de introducir formas sencillas de luchar contra las plagas, en la práctica de la piscicultura, rociando la totalidad de la extensión del estanque durante toda la temporada de desarrollo del pez. Se discuten los factores que hay que tener presentes al seleccionar nuevos plaguicidas para los peces.

Se exponen tres grupos principales de enfermedades que atacan a los peces en los estanques: endoparásitos, ectoparásitos y organismos que expelen productos tóxicos en el agua del estanque.

Asimismo se describe la posibilidad de identificar la toxina Prymnesium parvum, la exterminación de éste flagelado y de las algas verde-azules y los resultados de la lucha en amplia escala de los ectoparásitos Argulus, Lernaea y Dactylogyrus en los estanques piscícolas israelíes.

La presencia de ectoparásitos en las aguas interiores del Medio Oriente y Africa revelan la presencia de grandes reservorios de infección potencial para los peces cultivados en estanques. Se proponen medidas precautorias para impedir los peligros de las infecciones parasitarias y facilitar el desarrollo en gran escala de la piscicultura.

1 INTRODUCTION

Although diseased fish occur in nature, the diseases are particularly liable to become epidemic in intensified fish culture because of (i) the large quantities of organic material in the ponds due to fertilization and great quantities of supplementary feed, (ii) the stagnant water with relatively high temperatures, and (iii) the crowded populations of fish. Furthermore, the increasing concentration of fish ponds in specific areas with waterway connections from one farm to another and between the various areas, enhances the possibility of diseases spreading. Also, the introduction of foreign fish allows the penetration of new ectoparasites and pathogenic bacteria.

In culture fisheries the whole population of a pond is sometimes killed, resulting in a loss of potential food and an economic loss to the culturist. On the other hand, there are several important factors which aid in combatting and efficiently controlling epidemics in artificial fish ponds. The growth period of fish in ponds is relatively short, in many cases the ponds are emptied after 150-200 days, whereupon the pond bottoms may be dried for a longer period, which is to some extent a form of "self disinfection".

The increased use of pesticides in agriculture also provides the fish culturist with new and more suitable therapeutic drugs which are distinguished by their selectivity to various parasites and other disease-causing organisms, without being harmful at those concentrations to their hosts, and only harmful to their food-animals to a limited extent.

This allows the introduction of new and simple methods for the control of pests by spraying the whole pond where the fish grow, with suitable substances. In this way each treated pond becomes lethal to the disease-causing organisms and there is no need to transfer the fish from the ponds for short-time baths or injections. The needed quantities of pesticides are in most cases relatively small, and the whole technique is cheap and easy. This method is especially suitable where fish ponds are small and easy to manage.

While selecting new pesticides for extermination of disease-causing organisms the following factors have to be taken into consideration:

(i) the difference between the lethal dose (LD) of the substance to the organism and to the fish must be great enough, at least 1:4,

(ii) the substance must dissolve easily in water,

(iii) its price must not add too much to the production costs, and

(iv) it should not restrict too seriously the productivity of the pond.

However, in some cases the health of the fish is more important than the productivity of the pond and the treatment must be carried out in any event. In storage ponds, where fish ready for marketing, or fingerlings stored for next season's stocking are kept in very crowded conditions, the extermination of disease-causing organisms is more important than the natural productivity of the pond. In spawning ponds the very small fry, which have not yet reached the size suitable for removal, are attacked by many gill parasites which may destroy total populations in a very short time. The control of diseases is here more important than any other consideration.

Even in fattening ponds the calculation of the effectiveness of spraying an agent into a pond must be considered individually for each case. Experience in Israel has shown that even in the cases when the natural-food population was affected by the spraying of the agent, the negative effect was of short duration only, and the population recovered after five to ten days.

It is of great importance that the pesticide should not leave residual elements harmful to men in the body of the fish, and that the agent should not be harmful to the workers who handle them, or to surrounding cultivated crops.

Surveys on fish diseases in Israel (Sarig, 1961; Paperna, 1964a), and other Near East countries (Sarig, 1963 - Questionnaire on carp diseases, submitted to the 6th and 7th sessions of the GFCM; Wunder, 1961), India (Tripathi, 1965) and many Japanese and African works on fish parasites (Nakai, 1927; Matsui and Kumada, 1928; Nakai and Kokai, 1931; Hoshima and Sahara, 1950; Fryer, 1958; 1961a; 1961b; Baker, 1960; 1963) have shown that fresh-water fish in rivers, lakes, reservoirs and ponds are subjected to heavy infestations of fish parasites and care must be taken to prevent great losses of fish populations especially in fish ponds where the dense stock of fish is of a high commercial value and preventive measures are now easy to adopt.

The diseases affecting fish can be divided into three groups:

(i) fish mortality due to organisms in the water which affect the fish by excreting toxic products and without direct contact,

(ii) ectoparasites, and

(iii) endoparasites, bacterial or viral diseases.

2 ORGANISMS EXCRETING TOXIC PRODUCTS

Of the first group of diseases mentioned above there are two instances which seriously harm the fish breeding industry.

2.1 Prymnesium parvum

Prymnesium parvum Carter is an organism confined specifically to brackish water with salinities higher than 250 mg/Cl⁻/l. Fish kills due to this flagellate are known in Israel where almost 60 percent of the fish ponds are infested and the annual loss in 1960 reached nearly $100,000 (Sarig, 1961). In Europe great damage was caused by Prymnesium in England (Farrow, Lincolnshire River Authority, 1965 - personal communication) and in Bulgaria (Petrova, 1962). In the Near East, African and Asian countries the occurrence of this pest is not yet known. But the growing tendency, especially in subtropical regions to exploit inland brackish water for intensive fish culture may give the problem world-wide importance.

Many investigations in pure cultures of Prymnesium and field studies carried out in Israel have provided us with considerable information on the ecological requirements for its development, the properties of its toxin, techniques for determination of sub-lethal doses of toxin in ponds and ways of exterminating the flagellate (see the numerous papers listed in the references by Reich et al., 1947-1963; Shilo et al., 1953-1964; Rotberg, 1958; Parnas and Spiegelstein, 1963; Koch, 1963; Yariv, 1955; Sarig, Lahav and Vardina, 1960; Sarig and Lahav, 1961).

It was found that ammonium sulphate at a concentration of 10-15 ppm (Reich and Aschner, 1947), aqueous ammonia at concentrations of 10 ppm (Sarig, Lahav and Vardina, 1960), copper sulphate at 2 ppm (Shilo et al., 1954) and Lignasan (phenyl mercuric acetate) at a concentration of 0.5 ppm (Sarig and Lahav, 1961), effectively destroys Prymnesium parvum. The effect of ammonium sulphate and aqueous ammonia was found to be limited by external factors such as pH, temperature and salinity.

2.2 Blue-green algae

Blue-green algae, especially Microcystis, Anabaena, Spirulina and Oscillatoria sp., develop heavy water blooms in fish ponds due to higher temperature and organic and mineral content of the water because of heavy fertilization and feeding. Many cases of fish and livestock poisoning by toxic water have been shown to be associated with blue-green algae blooms (Shilo and Shilo, 1964).

It is not only the toxicity of these algae that endangers the fish in ponds. Sudden decomposition of great quantities of these algae, caused by still unexplained ecological changes, are followed by mass mortalities of the fish due to oxygen depletion. Damage caused to fish ponds by blue-green algae is widely known in Israel and suspected in Turkey and Morocco (Sarig, Final Report to the 7th Session of the GFCM on: "Carp Culture, Continuation of the Study on Carp Diseases" - unpublished).

Tripathi (1965) mentioned mass mortalities in Indian ponds due to oxygen deficiencies because of the accumulation of too much oxidizable organic matter at the bottom of the pond. It is suspected that these accumulations are also the results of heavy blooms of blue-green algae. The same suspicion exists also in some other African and Near East countries, but this is not certain due to lack of adequate facilities for diagnosing diseases.

Many algicides are recommended for the control of blue-green algae. Most of them are still too expensive for large-scale application in ponds (CMU, Diquat or Paraquat). Copper sulphate is at present the most popular algicide. But in many cases the successful mass destruction of the blue-green algae by this substance in ponds with a heavy population of fish caused massive fish mortalities due to oxygen depletion (Shilo, 1951). Better results and prevention of those fish mortalities were obtained when copper sulphate was used prophylactically to prevent the occurrence of the water blooms (Kessler, 1960). Recent investigations in the U.S.S.R. (Mamontova, 1961; 1962; Mamontova, Komarova and Kalish, 1961) have shown that prophylactic prevention of blue-green algae blooms in fish ponds can be obtained also by frequent and heavy fertilization with nitrogen fertilizers at the beginning of the season.

3 ECTOPARASITES

Ectoparasites form the largest group of disease-causing organisms in fish ponds. As has been mentioned above, suitable conditions such as long periods of temperate climatic conditions, high organic matter levels, and increased density of the fish population in the ponds, strengthen the potential possibility of epidemic outbreaks. In Israel the ectoparasites present a specially severe problem because of consumer sensitivity.

Argulus and Lernaea are the most widely spread skin parasites. In Israel, they infest almost all fish species throughout the year and cause damage to small fingerlings (Reich, 1949). The open wounds, caused by the attaching parasites, open the way for secondary infection by bacteria. There is also a belief that Argulus is responsible in some way for the occurrence of the skin disease epithelioma (Sarig and Lahav, 1958). Heavy infestation of fish ponds with Argulus was noted in all Near-East countries (Sarig - unpublished). No data are available on damage caused by Argulus to fish in African ponds but, Fryer (1963; 1965b) described the occurrence of many species of this parasite on most of the African commercial fishes, mainly those which thrive in lakes. He mentioned also the occurrence of other crustacean parasites such as Lamproglena and Ergasilus which are known in Europe as seriously infecting gills of fish (Schäperclaus, 1954).

Lernaea infection has occurred as an epidemic in Israel since 1958 and continues to cause great damage to fish populations (Yashouv, 1959; Shilo, Sarig and Rosenberger, 1960; Lahav and Sarig, 1964). The information collected from Near East countries indicates that this skin parasite is widely distributed. Fryer (1963; 1965) counts at least 10 species of this parasite on African fish. Experimental fish ponds in Nigeria were so heavily infested with Lernaea that it caused fish mortality and curbed the growth of the fish (Paperna, personal communication). Tripathi (1965) mentioned heavy mortalities of adult fish due to Argulus in Indian fish ponds.

Good results in eradication of *Argulus* were obtained in Israel by the use of Lindane sprayed directly into the pond at a concentration of 0.2 ppm of a 10 percent solution (Sarig and Lahav, 1958). Later, when signs of Lindane-resistance occurred, (Lahav, Shilo and Sarig, 1962) spraying the ponds or large quantities of fish in tanks with other effective insecticides was developed (Lahav, Sarig and Shilo, 1964). The substances and concentrations used are shown in Table I.

Table I

Treatment for eradication of ectoparasites of fish

Parasite	Chemical agent sprayed		Concentration ppm of active ingredient	Exposure time hours	Lethal doses to carp ppm of active ingredient
Argulus sp.	Lindane	1)	0.02	6	20 - 25
	Malathion	2)	0.25	6	25 - 30
	Dipterex	3)	0.25	6	30
	D.D.V.P.	4)	0.25	6	30
	Bromex-50	5)	0.15	-	2
Lernaea (adult)	Potassium permanganate		25.00	1.5	40
" (Copepodid)	Dipterex		0.25	6	
	D.D.V.P.		0.25	6	
	Bromex-50		0.20	-	
Dactylogyrus vastator	Dipterex		0.40	30	
	Bromex-50		0.20		
D. extensus	Dipterex		0.40	30	
	Bromex-50		0.35		

1) Gama isomer of Hexa-chloro-cyclo-hexane
2) Malathion - 0.0-dimethyl S-(1,2-dicarboethoxy-ethyl) dithiophosphate
3) Dipterex - 0.0-dimethyl 1-hydroxy-2-trichloromethyl phosphate
4) D.D.V.P. - 0.0-dimethyl 0-2-2-dichlorovinyl phosphate
5) Bromex-50 - dimethyl 1,2-dibrome-2,2 dichloroethyl phosphate

In the case of *Lernaea*, no insecticide was found suitable until recently for the eradication of the adult parasites from the fish in ponds. Potassium permanganate, at a concentration of 20 ppm was effective in a one hour bath, but caused also, from time to time, fish kills during the bath (Shilo, Sarig and Rosenberger, 1960). It was found later that 0.5 ppm of a 50 percent solution of Dipterex and Bromex are very effective against the copepodid stage of *Lernaea*. After three weekly sprayings in infested ponds, which killed off the new copepodid generations, even heavily infested fish populations became free of adult parasites (Lahav, Sarig and Shilo, 1964).

Monogenetic trematodes, especially Dactylogyridae, are widely spread in Israel and other Near East countries as well as in Africa on a wide variety of fish species (Paperna, 1959; 1960; 1961; 1964b). In Ghana, at least five species of monogenetic trematodes infecting Cichlidae, and some others on Clariidae are known (Paperna - personal communication).

Dactylogyrus vastator has long been known as one of the most harmful organisms on the gills of very small fish in spawning ponds (Schäperclaus, 1954). In Israel, losses of hundreds of thousands of fishes have been known for many years. Recent investigations in Israel have shown that one spraying in spawning ponds, even when the fry are only six or seven days old, with 0.8 ppm of a 50 percent solution of Dipterex is sufficient to free the fish from the parasites attached to their gills (Sarig, Lahav and Shilo, 1965).

A survey of inland waters in Israel, carried out by Paperna (1964a) revealed the occurrence of 116 species of the metazoan parasite fauna which may serve in some circumstances as a natural reservoir for potential infection of fish in ponds.

More species of various ectoparasites have appeared in Israel only in the last two or three years, which have immediately caused considerable damage to the pond fish, for example Costia sp. and Ichthyophthirius sp. Other ectoparasites like Trichodina or Chilodonella sp., which are known in Europe as secondary parasites which attack weakened fish only, caused direct fish mortalities in Israel in many cases. These two phenomena indicate again the potential danger of unexpected developments in sub-tropical or tropical climatic conditions.

4 ENDOPARASITES

Bacterial or endoparasitic diseases are less common in this geographical area. Ascites (infectious carp dropsy) which causes great losses in Europe, appears in the Near East countries (south of the European coast of the Mediterranean Sea) on a small scale only and not as an epidemic.

Paperna has described a new genus of endoparasitic monogenetic trematode, Enterogyrus cychlidarum, parasitic in the intestines of Tilapia sp. in rivers in Israel (Paperna, 1963a). Baker (1960) has described trypanosomes from the blood of fresh water fish from East Africa. It is still not known whether endoparasites may become more dangerous with the increased fish culture industry in these regions.

5 OTHER CAUSES OF MORTALITY

Mass mortalities caused by oxygen deficiency are also widely known in Israeli fish ponds, due to high water temperature, the heavy water blooms and the high density of fish populations. To prevent these mortalities, important measures adopted are the supply of fresh water to the pond during the whole growing season, especially at night, and the use of suitable technical equipment for oxygenating the pond water (Marek - unpublished).

6 CONCLUSIONS

In conclusion it may be stated that toxin-producing algae, ectoparasites and oxygen deficiencies may seriously endanger the development of fish culture in tropical and subtropical regions. Even if, in the first years of fish culture this danger is not pronounced, the spread of various epidemics may be expected with the further development of the industry, ageing of the ponds and introduction of exotic fish species.

Precautions should be taken in advance against this potential development. The most important are: (i) formation of teams of skilled research workers and qualified field staff, (ii) establishment of experimental stations and laboratories for research and experimental work, (iii) survey of potential sources of disease-causing organisms, and (iv) studying the adaptation of known pesticides to local conditions and development of new agents for extermination of disease-causing organisms.

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IX/R-3

A REVIEW OF THE PARASITES AND DISEASES OF FISHES IN WARM-WATER PONDS IN NORTH AMERICA

by

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Abstract

Disease problems of bacterial, viral, fungal, algal, helminth, copepod, and annelid origins are discussed in detail. The importance of each to the American fish culturist is discussed, its economic importance cited, and the developmental stages or species of fish most susceptible listed. Applied treatment and the limitations of each are given for the various diseases, along with references to important research works pertinent to each case. Personal experience of the author, based on data accumulated in the diagnostic laboratory at the Fish Farming Experimental Station, are included.

Gaps in existing knowledge, short-comings of currently applied treatments, and promising areas for continued research are indicated.

ETUDES DES PARASITES ET DES MALADIES DES POISSONS DANS LES ETANGS A TEMPERATURE ELEVEE EN AMERIQUE DU NORD

Résumé

La communication traite en détail des problèmes que posent les maladies causées par des bactéries, des virus, des champignons, des algues, des helminthes, des copépodes et des annélides. Elle examine l'importance de chaque maladie pour les pisciculteurs américains, ses incidences économiques et le stade de développement ou l'espèce de poisson le plus susceptible d'être atteint. L'auteur décrit les traitements des diverses maladies et les limites dans lesquelles ils peuvent être appliqués, en signalant les principaux travaux de recherche, se rapportant à chaque cas. Il fait aussi part de son expérience personnelle, basée sur les données accumulées au laboratoire de diagnostic de la Fish Farming Experimental Station.

La communication contient des indications concernant les lacunes dans les connaissances acquises, les défauts des traitements actuels et les domaines prometteurs pour les futurs travaux de recherches.

EXAMEN DE LOS PARASITOS Y ENFERMEDADES DE LOS PECES EN LOS ESTANQUES DE AGUAS TEMPLADAS DE AMERICA DEL NORTE

Extracto

Se examinan detalladamente los problemas que plantean las enfermedades producidas por bacterias, virus, hongos, algas, helmintos, copépodos y anélidos. Se estudia la importancia que tienen cada uno de dichos problemas para los piscicultores norteamericanos, se expone su importancia económica, se indican las especies de peces o las fases de desarrollo de éstos que son más susceptibles a las enfermedades. Se exponen los tratamientos aplicados y las limitaciones de cada uno con respecto a las distintas enfermedades, junto con referencias a los importantes trabajos de investigación relativos a cada caso. Se incluyen las experiencias personales del autor basadas en los datos acumulados en el laboratorio de diagnóstico de la Estación Agrícola Experimental para la Cría de Peces.

Se indican las lagunas que existen acerca del conocimiento de estos problemas, los defectos de los tratamientos que se aplican normalmente, y las mejores zonas para llevar a cabo una constante investigación.

1 INTRODUCTION

The detection and treatment of the diseases of warm-water fishes in the United States has long been a neglected science. Extensive programs for the propagation of trout and salmon created an early emphasis on the diseases of these species. The very success of warm-water fish culturists on the other hand contributed in no small part to this attitude. Losses due to disease were easily offset by over-production since spawning the fish was often no problem. In many cases, expected mortalities were taken into consideration when the annual production was planned. The development of private hatcheries and large-scale fish farms in recent years, the maintenance of which depended on a favourable cost-profit margin,no longer allowed such extravagance. Diseases and parasites were quickly recognized as major contributors to losses of fish and increased operating costs. Budget-conscious administrators of state and federal hatcheries who were responsible for the wise use of tax dollars also began to look for ways to cut production costs. Again, the control of parasites and diseases was a likely area in which to effect savings.

Much of the work on the treatment of the diseases of warm-water fishes prior to 1953 is well summarized in "Culture and Diseases of Game Fishes" by H. S. Davis (1956). The descriptions of diseases and bibliography provided in his volume are especially useful to the beginner working in the field of fish diseases. It is interesting to note that many of the "drugs of choice" in use today were mentioned by Davis. Other drugs reported in literature cited in his book have found new, and often, more effective uses. The most profound advances in the treatment of diseases of warm-water fishes have been made through the application of antibiotics and insecticides. Antiseptics, antibiotics, insecticides, anesthetics, and herbicides are available in greater numbers than ever before and many remain untested for their potential use in fish culture.

During the past five years, a concerted effort has been made to check the bacterial and parasitic diseases of warm-water fishes. Research at such government-sponsored laboratories as the Fish Farming Experimental Station, Stuttgart, Arkansas; the Southeastern Fish Cultural Laboratory, Marion, Alabama; the Eastern Fish Disease Laboratory, Leetown, West Virginia; and the Western Fish Disease Laboratory, Seattle, Washington has contributed greatly to the knowledge on this subject. In addition, extensive research on diseases is underway at Auburn University, Auburn, Alabama and at Southern Illinois University, Carbondale, Illinois. Individual researchers whose interests are related to fish diseases may be found at many colleges and universities. An awareness of the excellent use which may be made of fish as bioassay tools or as laboratory animals has stimulated interest in research involving their physiology and metabolism.

Although many chemicals are named in the following pages, their mention does not constitute recommended procedures. Current regulations imposed by law and administered by the Food and Drug Administration prohibit their use in the United States unless prior approval has been given. At the time of writing, no compounds have been cleared by the Food and Drug Administration for use on fishes intended for human or animal food. Certain chemicals may be used on bait and ornamental fishes without objection, but prior approval should be received if the user is in doubt.

This review is not intended to provide a complete discussion. An attempt has been made to select papers which contribute significantly toward knowledge concerning a particular disease, but it is realized that many may have been overlooked. No attempt has been made to list all of the species of each genus of parasite or the hosts on which they may be found. In cases where treatments were similar for a large group of parasites, i.e., as in the external protozoans, the names of the genera involved are given and discussed as one. Many species of parasites may be found in a single genus such as Dactylogyrus, but it is not the purpose of this paper to attempt to explain the subtle differences between them.

2 BACTERIAL DISEASES

The chemical control of bacterial diseases of warm-water fishes in America is a comparatively recent undertaking. Prior to 1950, most efforts to control fish diseases of bacterial origin centred on quarantine, pond sanitation, and improved management techniques. In some areas of the United States, losses due to bacterial infections were considered routine, and deficiencies in production were generally offset by stocking extra breeding stock. While partially successful, such techniques were accompanied by numerous other problems such as overcrowding and starvation.

Chemical control of fish diseases were apparently first considered around 1950. Slater (1948) attempted to control columnaris disease with sulfa drugs. Snieszko (1954) reported that, at that time, he was aware of but four successful efforts to control diseases caused by *Aeromonas* and *Pseudomonas* spp. bacteria. Of these, Smith (1950) and Ambrus, *et al.*,(1951) successfully treated frogs with chloramphenicol. Seaman (1951) treated rainbow trout (*Salmo gairdneri*) with sulfamerazine while Wagner and Perkins (1952) reported the successful treatment of rainbows with a mixture of sulfathiazole and sulfamethazine in combination with some antibiotics . Subsequent to these reports, numerous other successful treatments have been reported. These will be discussed with relevance to the individual diseases.

2.1 Hemorrhagic septicemia

Hemorrhagic septicemia, a systemic infection of fish caused by *Aeromonas liquefaciens*, is generally considered to be the most important disease of warm-water fishes. This disease has been identified from all species of fish checked thus far at the Fish Farming Experimental Station (Meyer, 1964) and has been responsible for extensive losses throughout the country (Snieszko,1954; Griffin and Snieszko, 1951; Reed and Toner, 1942; Lewis and Bender, 1960; Meyer, 1964; Rock and Nelson, 1965). Although taxonomists may yet disagree as to its correct taxonomic position, there can be no doubt as to the virulence of this organism. Useful information for the separation of *Aeromonas* and *Pseudomonas* groups of bacteria has been provided by Bullock (1961a and b; 1964).

Early attempts with chemotherapeutics concerned the addition of selected chemicals to the water inhabited by diseased fish. Although this technique was probably effective in controlling the spread of the disease from infected to healthy fish, it was too expensive for use in ponds or in large-scale operations. Seaman (1951) reported that he had successfully combatted a bacterial disease in rainbow trout by including 15 g of sulfamerazine in the daily feed per 100 pounds (45 kg) of trout. Snieszko (1954) suggested that Terramycin be included in the ration of pond fish for hermorrhagic septicemia. Schäperclaus (1956) reportedly obtained substantial reduction of mortalities in carps by intraperitoneal injections 2 - 5 mg of chloramphenicol per 100 g of fish. Snieszko (1958a) recommended that either or both of these techniques be incorporated in fish cultural practices. One of the first large-scale efforts at combatting an epizootic was reported by Meyer (1964) in which a 40-acre (16 ha) reservoir stocked with approximately 600 pounds of golden shiners (*Notemigonus crysoleucas*) per acre (666 kg/ha) was successfully treated by incorporating oxytetracycline (Terramycin) in the daily ration at 2.5 g per 45 kg of fish per day for 10 days. This technique has been successfully applied on numerous occasions since then.

Intraperitoneal injections of chloromycetin or oxytetracycline are now standard procedures whenever wild fish are brought to our station for experimental use. Prior to the adoption of this procedure, it was impossible to control losses of such fish due to hemorrhagic septicemia. Although no published accounts have been found, it is understood that this technique has also gained wide-spread acceptance. Dosage rates vary between 20 and 50 mg per kg of body weight. Use of antibiotics in this manner has provided fish culturists with a method to control the usual die-off when brood-stock fish such as bass are stocked in spawning ponds.

Currently, oxytetracycline (Terramycin) has proved to be the only drug economically feasible for use in large-scale fish cultural operations and its use by commercial producers of warm-water fish has become wide-spread in the United States. However, several other drugs have continued to show their effectiveness in experimental tests. Chloramphenicol, Kanamycin, and Tetracycline have all proved effective but each has proved too expensive for the treatment of infections in large ponds. Conroy (1963) reported that Kanamycin was effective when administered intraperitoneally but that it was ineffective when given orally. Although sulfonamides have been suggested for the control of Aeromonas infections, we have had poor success in combatting hemorrhagic septicemia with this group of drugs. Similar findings concerning sulfonamides are reported by Snieszko and Bullock (1962). Likewise, although nitrofurans such as furazolidone and nitrofurazone have indicated effectiveness under laboratory conditions, field tests with these compounds have not been encouraging. These findings are in general agreement with those found by Clemens (personal communication).

Although topical treatments for Aeromonas liquefaciens are generally ineffective, it is worthwhile to note that the use of certain antiseptic or bacteriostatic agents as a water additive during the transport or handling of fish is helpful. Acriflavin has proved highly effective in controlling the spread of the disease when used at 3-10 ppm (unpublished work at our station). Snieszko and Bullock (1962) indicate that chloramphenicol, oxytetracycline, chlortetracycline, and a mixture of penicillin and streptomycin are all effective as water additives at rates of from 10 to 50 mg/ℓ.

Someday it may be possible to render the fish resistant to bacterial infections such as hemorrhagic septicemia. This might be accomplished in one of several ways. Best of all, perhaps would be the development of resistant strains of fish, but thus far no organization has had the funds to undertake this rather long-term project. Another technique might be the inducement of an artificial immunity in cultured fish, much like that utilized in human or veterinary medicine. Meyer and Collar (1964) found that it was possible to inject large numbers of fish with an antibiotic. Although the vaccination of large populations of fish is unlikely with this type of procedure, it might prove feasible in the future. A number of workers have proceeded on the theory that it may be possible to immunize fish using oral antigens (Duff, 1942; Krantz, *et al*., 1964; Ross and Klontz, 1965). Although these efforts have been only partially successful, it is possible that this may eventually prove the most feasible method for combatting fish diseases.

We know little of the immune responses of fishes. Hildemann (1956) has found that antibody subpopulations occur within groups of fish and that extreme individual differences exist. Temperature apparently plays an important role in the production of antibodies in fish (Bisset, 1946 and 1948; Cushing, 1942; Smith, 1950) with little or no antibody production below 10°C. Bisset (1947) has expressed the opinion that at low temperatures a type of balanced parasitism exists in infected fish, in which the natural defenses of the fish are unable to restrain the invasiveness of the bacterium, but the pathogen is unable to overwhelm the system of the fish due to greatly reduced enzyme activity. Thus, the bacteria and their host, which are mutually tolerant of each other at low temperature, become intolerant at high temperatures. Differences in metabolic rates between the two may thus explain the heavy mortalities which occur in warm-water fish ponds during the spring and fall seasons.

From the foregoing discussion, it is obvious that much remains to be learned about the physiology of both the pathogen and its host. Even so, the knowledge at hand suggests that this area probably represents one of the most fruitful fields for future exploration.

The possible involvement of viral agents in the development of hemorrhagic septicemia (abdominal dropsy) remains unresolved. Evidence both pro and con is available, but no one has been able to demonstrate conclusively the role of each in initiation of the disease. The accumulating data at hand suggest that it is highly possible that two diseases with similar symptoms might be involved.

2.2 Pseudomonas infections

Bacterial infections due to the genus Pseudomonas are common in warm-water fishes in America. Identification of the various species involved has been difficult, but recently progress has been made in the separation of members of this genus by serological methods (Liu, 1961).

Numerous infections in fish due to bacteria of this group have been reported in the literature (Wolf, 1937; Snieszko and Bullock, 1962; Ross, *et al*., 1960; Seaman, 1951; Van Duijn, 1938; Rucker and Whipple, 1951; Griffin and Snieszko, 1951; Meyer and Collar, 1964; Bullock, 1965).

Successful treatment of such infections was reported by a number of workers. Snieszko and Bullock (1962) indicated successful treatments of trout with chloramphenicol and Terramycin, but a lesser effectiveness with sulfonamides. Meyer and Collar (1964) effectively controlled infections of Pseudomonas fuorescens in catfish by either intraperitoneal injections of Kanamycin (25 mg per 0.45 kg of body weight) or by feeding Terramycin in the daily ration (2.5 g per 45 kg of fish per day). Chloramphenicol and sulfonamides showed no activity in *in vitro* tests. Conroy (1963) indicated that he, also, obtained control by the injection of Kanamycin (40 mg per kg of body weight).

2.3 Columnaris disease

Diagnosis of columnaris disease in fish is usually based on the presence of myxobacteria in typical external lesions on the mid-dorsal areas of the body or in mucus membranes such as those in the mouth region. Such symptoms have given rise to descriptive names for the disease such as "saddleback disease" or "cotton mouth disease". An excellent description of the disease and etiological agent may be found in Davis (1956). Unfortunately, these symptoms. although usually typical of columnaris disease, may be produced by a variety of pathogens. Consequently, it is difficult to ascertain positively the correct identity of the causative organism in reported cases unless bacteriological examinations were made.

The apparent fastidiousness of the pathogen (Chondrococcus columnaris) has made isolation difficult. Certain laboratories have reported repeated success in the isolation of this organism (Garnjobst, 1945; Ordal and Rucker, 1944) but others, such as our laboratory, have had a singular lack of success in the artificial culture of this bacterium even on media used successfully at the other stations. This diversity of results may be due to a number of factors; differences in strains or species of bacteria, rigid requirements as to its optimal thermal range, or perhaps to a completely erroneous diagnosis of the disease. The variable degrees of success with which reported cases of this disease have been treated also suggests that this disease and its pathogenic agent are, as yet, poorly defined.

Control of the disease has been difficult. Slater (1948) reported a successful attempt to control infections by including sulfadiazine and sulfamerazine in the food of salmon. Other sulfa drugs gave less favourable results. Johnson and Brice (1952) reported that they successfullly controlled columnaris disease with sulfamerazine, but in a later publication (1953) they reported that the drug gave only partial temporary control. Snieszko (1958b) indicated that the use of sulfa drugs was only slightly successful and suggested that antibiotics be tried as medications to be included with the feed of infected fish. We have tried Terramycin in feed with success in large ponds.

Various topical treatments have been applied. Davis (1956) recommends the use of copper sulphate as a one to two minute dip in a solution of 1:2,000. Bryant (1951) claimed that the use of PMA successfully prevented extensive losses of trout due to this disease. Snieszko (1958b) reported that dipping the fish in a 1:15,000 solution of malachite green for 10-30 seconds was recommended for treatment of external lesions. Copper sulphate at the rate of 1 ppm was suggested for treating warm-water fish ponds. Aureomycin at a concentration of 10-20 ppm or Chloromycetin at 5-10 ppm was also recommended. Lawrence (personal communication) has indicated that 1 ppm of Diquat, an herbicide, apparently suppressed columnaris disease in pond conditions. At our station (unpublished work) we have found that 6.0 ppm of Diquat will control the disease if it is confined to cutaneous lesions, but that concentrations up to 50 ppm have no effect if the infection has become systemic.

The diversity of results from the various treatments is perhaps due to the fact that fish may harbour cutaneous lesions, systemic infections, or both. Apparently as long as the disease is confined to strictly external lesions, control has been successfully achieved. Once the infection has become systemic the disease is usually fatal.

Columnaris infections may also be enteric. Fish have been found to harbour heavy infections within the intestine on infrequent occasions. Although the premise is not yet proved, there appears to be a direct relation between the infection of predatory species and their having fed on fish disabled by the disease. As an example, in a large lake in Arkansas, largemouth bass (Micropterus salmoides) weighing upwards of four pounds (1.8 kg) suffered a heavy mortality due to columnaris, apparently from feeding on gizzard shad (Dorosoma cepedianum) which were heavily infected with the bacterial disease. Bass which were too small to feed on the disabled shad were healthy, and no dead of this size were observed (Mathis, personal communication).

Under natural conditions the disease frequently attacks a single species of fish and may eliminate most individuals of that species without affecting others, except in a situation such as that described above. Black bullheads (Ictalurus melas) and crappies (Pomoxis sp.) are among the most susceptible.

Outbreaks of columnaris appear to be related to unfavourable environmental conditions such as low oxygen levels or accumulations of metabolic by-products. Though it is most frequently encountered during the hot summer months, the disease occurs throughout the year. In each case, when winter infections have been observed, ice cover remained over heavily stocked ponds for several weeks. As the ice receded, heavy mortalities due to columnaris occurred.

Currently, the inconsistencies in diagnoses of this disease have made it difficult to evaluate the results of various treatments. At our station, we do not feel confident that the various cases we designate as columnaris infections are all similar. Difficulties with the artificial culture of the pathogen have made it difficult to provide reliable data concerning its sensitivity to drugs, and have not permitted work with experimentally infected fish. Furthermore, the taxonomy of the Myxobacteria leaves much to be desired, and a comprehensive study of this group is needed to help differentiate between species or strains.

2.4 Streptococcus infections

Gram positive bacteria have generally been regarded as non-pathogenic to warm-water fishes. Although several species are known to produce diseases of salmonids, notably the corynebacteria which cause kidney disease, gram positive organisms are uncommon pathogens of fish. During 1965, a gram positive Group B Streptococcus was found to be the etiological agent of a disease causing heavy mortalities in golden shiners (Notemigonus crysoleucas). The organism was isolated on two separate occasions during the year and indications are that it may have a wider distribution than first expected. Testing in the laboratory has shown it to be lethal to bluegills (Lepomis macrochirus), green sunfish (Lepomis cyanellus), and to American toads (Bufo americanus), as well as to golden shiners. Other native species of fish appeared unaffected, as did chicks, mice and hamsters. A manuscript describing this disease is now in preparation.

The appearance of an organism in a group otherwise considered to be relatively non-pathogenic to fish indicates that the study of the bacterial pathogens has only begun. As fish culture becomes more intensive, we can expect to encounter additional organisms which may previously have been overlooked in mortalities which occurred in natural waters. Also, as population densities increase with intensive culture, the effects of crowding, poor water conditions, inadequate nutrition, or other stress conditions may induce pathogenic effects from otherwise saprophytic bacteria.

2.5 Pasteurella infections

Snieszko, et al., (1964) reported an epizootic among white perch (Roccus americanus) and striped bass (Roccus saxatilis) in Chesapeake Bay. Results of their investigations indicated that the mortalities were due to infections of a Pasteurella sp. bacterium. This represented the first known case of a fish disease caused by bacteria of this genus. An increased awareness of fish diseases and the use of diagnostic laboratories may indicate that organisms of this group are, indeed, true pathogens of fish.

2.6 Nocardia infections

Infections of Nocardia asteriodes in trout have been reported from two localities. One occurred in Argentina; the other represented a double outbreak at the same hatchery in West Virginia (Snieszko et al., 1964a,b). Snieszko and his associates indicated that the organism was weakly pathogenic to fish but pointed out that the route of infection was probably through contaminated feed. This suggests that the increased use of artificial feeds in warm-water fish culture may introduce additional problems of bacterial etiology from organisms heretofore considered non-pathogenic, and that care must be taken to ensure that only feeds of good quality are provided.

2.7 Miscellaneous bacterial diseases

In addition to the foregoing diseases for which pathogens have been isolated and their virulence established, a number of poorly understood maladies of fish are sometimes encountered. In most of these, bacteria are generally found but it has not been possible to demonstrate their role in the development of the condition. These include such diseases known as fin rot, bacterial gill disease, peduncle disease, and the so-called "winter fungus". In all cases, it has been possible to isolate bacteria from the vicinity of the lesion but attempts to produce similar symptoms in other fish by introducing the organisms into the body have been unsuccessful.

Fin rot. This name has been given to a condition in which the margins of the fins become necrotic and slough away. Generally the condition is associated with adverse physical conditions in which the fish are being held. Over-crowding, handling during excessively hot weather, or poor environmental conditions have all been found to induce this disease in warm-water fishes. Treatment of the condition varies. Frequently, alteration of the environment resulting in improved water quality will effect a "self-cure" under pond conditions. In tanks and aquaria, any good disinfectant seems to control the disease. Irwin (1959) reported that very low levels of Terramycin effectively controlled the condition, but that aureomycin and streptomycin were ineffective. Axelrod and Schultz (1955) suggested a variety of compounds including acriflavin, silver nitrate, potassium permanganate, and several antibiotics. Our experience has shown that 3 ppm acriflavin is a good prophylactic treatment and that potassium permanganate is also useful. Treatment levels of the latter must be varied with water chemistry and the species of fish involved. Generally speaking, hatcheries in which this disease occurs should initiate a good program of sanitation.

Bacterial gill disease. A bacterial gill disease of salmonid fishes has been well described by several workers with excellent reports supplied by Rucker, et al., (1952) and Wood and Yasutake (1957). Some of the confusing factors associated with this disease are discussed by Snieszko (1958c) who states that the disease is known only from salmonid fishes. An apparently similar condition has been found in warm-water fishes and, in all cases, myxobacteria similar to those described for the salmonid syndrome have been observed. In advanced cases, necrotic margins appear over the gill arches and the fish exhibit symptoms of anoxia. Crowding associated with unfavourable water chemistry has been observed during outbreaks but its role in inducing the disease is unknown (Wellborn, personal communication). Treatments generally prescribed for columnaris disease have been effective but improvement of the aquatic environment is considered the most helpful measure.

Many of the diseases discussed thus far have indicated a paucity of knowledge concerning the physiological effects of poor water chemistry and otherwise unfavourable conditions in the environment. While it is generally conceded that fish under stress are more susceptible to disease than other fish, the physiological effects of these factors are still poorly known.

Peduncle disease and "winter fungus". The symptoms of these diseases may actually be due to a complex of pathogenic organisms or of pathogenic and saprophytic organisms. In warm-water fishes a variety of organisms may be isolated from diseased fish (unpublished work, our laboratory) including Aeromonas liquefaciens, Pseudomonas sp., Chondrococcus columnaris, and some additional forms known to be saprophytic water bacteria. These organisms may occur singly or in combination with a water mold. Lesions produced by the bacteria themselves are similar to highly advanced cases of fin rot and are always fatal. In these the caudal fin may be completely lost. An inflamed margin precedes the progress of the lesion but an infected fish may linger for days before succumbing. Generally speaking, the condition is not highly contagious and it is not uncommon to see isolated individuals in an otherwise healthy population of fish.

When the above condition is accompanied by a water mold such as Saprolegnia or Achlya, fish culturists frequently refer to the disease as "winter fungus". Infected fish may carry extensive growths of fungi which in turn collect debris, diatoms, and a variety of aquatic organisms. Attempts to pull the tufts from the area of the lesion will usually remove muscle tissue with the mycelia. Fish infected with such multiple infections quickly lose stamina and succumb more rapidly than fish in which the fungal growth is lacking. In the laboratory it has been possible to remove the fungus infection through the use of fungicides, leaving the afflicted fish with large areas of the posterior skeletal elements completely exposed. The fish usually dies soon thereafter but it is amazing that a fish sometimes survives such damage.

As indicated above, Chondrococcus columnaris may be isolated from the lesions. In such cases the disease may develop into acute cutaneous lesions with a rapid rate of loss. These cases, however, should be considered columnaris disease rather than peduncle disease.

Treatment of peduncle disease is generally not warranted unless columnaris disease is indicated. The low rate of communicability indicates that it is not likely to spread throughout the population. General sanitation is probably the best preventive.

3 VIRAL DISEASES

Viral diseases remain a largely un-investigated field in warm-water fish culture in the United States. Such diseases in salmonids are receiving great emphasis and new strains are identified annually. In warm-water fishes, however, only lymphocystis has received more than passing attention. It is to be anticipated that as some of the more readily observed diseases of parasitic or bacterial etiology are identified and controlled, more and more attention will be focused on the possible role that viruses may play in the maladies of warm-water fishes.

A good summary of the knowledge relative to lymphocystis disease is provided by Wolf (1964) and Weissenberg (1965). A lymphocystis-resistant strain of walleye (Stizostedion vitreum) has been identified from a lake in Oklahoma (O'Reilly Sandoz, personal communication). The determination of resistant strains provides one of the most promising methods for combatting such diseases under natural conditions. Research toward the establishment of additional cell lines for tissue culture and the screening of materials from diseased fishes should contribute greatly toward our knowledge of the role viruses might play in diseases currently accepted as being caused by other agents.

The role of viral agents in epizootics of infectious abdominal dropsy is still open to question. Evidence both pro and con is available and further study is needed before the question can be resolved. It must be considered that viral and bacterial agents may induce a synergistic response, as well as that it is possible that both may induce separate diseases that have similar manifestations. Such an observation is reported by Tomasec and Fijan (1965). Summary of the views of various workers concerning the relationship of viruses and bacteria to hemorrhagic septicemia may be found in papers by Schäperclaus (1965), Goncharov (1965), Volk and Havelka (1965), and Tomasec and Fijan (1965).

4 FUNGUS INFECTIONS

Growths of water molds (Saprolegniaceae) are common in the aquatic environment on most forms of decaying organic matter. Occasionally growths will appear on fish or fish eggs under incubation and attention must be given to their control. Although some forms (*Saprolegnia invaderis* and *Saprolegnia parasitica*) are known to be primary invaders of fish, most of them are saprophytic opportunists taking advantage of necrotic tissue associated with injuries, bacterial or parasitic lesions, dead and decaying eggs, or generally unsanitary conditions (Vishniac and Nigrelli, 1957; Davis, 1956; Scott and O'Bier, 1962; and Shanor and Saslow, 1944).

Treatment of the conditions, therefore, must be related to the circumstances involved. Infections on fingerlings and fry have been successfully treated with a great variety of chemicals including malachite green (Allison, 1954; Clemens and Sneed, 1958; Fish, 1938; Foster and Woodbury, 1936; Rucker and Whipple, 1951; and O'Donnel, 1941); copper sulphate (Hoffman, 1963; Fish, 1938; and Schneberger, 1941); potassium permanganate (Fish, 1938); acriflavin (Patterson, 1950); salt (Davis, 1956) and formalin (Fish, 1938). Eggs have been treated with most of the above chemicals with particular modifications added to adapt the treatment to the type of incubation involved. Burrows (1949) provides a good review of techniques.

The use of fungicides must be approached with caution since the toxicity varies greatly with the species of fish involved, the development stage of the fish, different lots of the compounds, and with the hardness of the water. For example, we have found that tolerances of malachite green varied greatly between carp (*Cyprinus carpio*), golden shiners, channel catfish (*Ictalurus punctatus*), and largemouth bass. Carp were most tolerant and largemouth bass were highly sensitive. Some of the results of other workers are summarized in Hoffman (1963). It should be emphasized that each station must determine the safe level to be used and that only an insight may be gained from the experience of others.

Currently the control of fungus has not been a major problem in the United States. Many hatcheries routinely treat their fish with formalin and malachite green prior to distribution to control external parasitism and to reduce the incidence of fungus infections.

5 ALGAL DISEASES

During recent years, workers have encountered organisms in the tissues of the skin and gills which could not be identified. Some of these organisms have since proved to be algal in nature. *Oodinium limneticum* and *O. ocellatum* have been recognized as parasites of fish for some time (Kudo, 1960) and have been known to induce mortalities. Hoffman *et al.*, (1960) reported the occurrence of a form resembling *Mucophilus cyprini* that was causing extensive losses in tropical fishes. More recently, *Chlorella* sp. has been identified from the tissues of bluegills, *Lepomis macrochirus*, (Hoffman *et al.*, 1965). We have observed alga-like organisms in the tissues of a variety of species, but their identity remains undetermined. In severe infections, the fish exhibited symptoms of distress and mortalities were occurring. Treatments with copper sulphate or acriflavin generally bring relief but the exact role of the organisms in the condition observed remains unproved.

A disease indirectly related to algal organisms is that of algal toxicosis. Heavy blooms of blue-green algae (Cyanophyceae) are known to produce conditions toxic to fish (Carl, 1937; Prescott, 1960; Rose, 1953; Ingram and Prescott, 1954). The presence of a toxin has been established by several workers, including Mackenthum *et al.*, (1948) and

Rose (1953). Dinoflagellates have also been shown to produce toxins which are lethal to fish (Muncy, 1963; Jurgens, 1953). Symptoms of the disease are superficially similar to those caused by oxygen depletion. However, oxygen depletions are accompanied by low oxygen levels, loss of the phytoplankton bloom, discolouring of the water, and a malodorous condition. In such situations, the fish are in greatest distress just before sunrise and mortalities usually end when the sun rises. During conditions of toxic algal blooms, the phytoplankton bloom may actually increase, adequate oxygen levels are present, no distinct odor change may be noted, and fish mortalities increase during the day. Fish exposed to algal toxins may die without symptoms. We have observed convulsive movements similar to those induced by chemical poisoning and necropsies of moribund fish have indicated severe inflammation of the kidneys. Attempts to isolate bacteria from affected fish in the above situation have proved negative.

Relief from the symptoms of algal toxicosis has been obtained by cropping the algal bloom with copper sulphate. Although I know of no cases in which they have been used for this purpose, algicides such as Karmex (diuron) (Sills, 1964) or Simazine should also prove effective. Care must be taken during the application of the algicide to avoid over-rapid kills of the algae since this may result in an oxygen depletion.

6 PROTOZOAN DISEASES

The impact of protozoan diseases of warm-water fishes on American fish culture is well recognized. Nearly all stations concerned with the production of fry and fingerlings now realize the importance of controlling this group of parasites. Even moderate numbers of these organisms on small fish may prove fatal since the infections may cause the fish to stop feeding. Fry and very small fingerlings cannot survive for any extended period without feeding, so infected fish may die without exhibiting any symptom other than debilitation. Symptoms are usually not striking and the behaviour of the fish is as useful in recognizing infections as is physical appearance. A notable exception occurs, however, in the case of ichthyophthiriasis. Infected fish may exhibit over-secretion of mucus, with the accumulated slime giving the fish a grayish or bluish appearance. Nervous twitching of the fins or body; scratching on any surrounding object, folding the fins, loss of appetite,loss of balance, erosion of the fins, and petechiae in the fins are frequently observed symptoms. Other symptoms may be observed but these are frequently associated with specific infections and will be described with the particular disease concerned.

6.1 Ichthyophthirius multifiliis

This parasite probably claims as many channel catfish (Ictalurus punctatus) fingerlings annually as all other diseases of this species combined. Although especially lethal to catfish, the disease attacks all native species of fish. It is fatal in many infections and, under certain circumstances, may be extremely difficult to control. Part of the problem in controlling this disease involves reservoir hosts. Brood stock left in the same pond with fingerlings may pass the disease on to their offspring. Wild fish of unrelated species may carry the disease with them if they gain entry to ponds used in fish culture. Although no species of fish is known to be resistant to the disease, goldfish seem to tolerate higher levels of parasitism than most other species of fish (Osborn, personal communication).

Identification of the disease is dependent upon observation of the developing trophozoites in the epithelial tissues of the host, but experienced culturists may be able to detect the disease long before the maturing forms are evident on the body of the fish. Fish under attack by this organism attempt to scratch themselves on any surrounding surface. Frequently the fingerlings will congregate in a large mass near the incoming water supply. Although most species of fish will carry the developing trophozoites over the entire body surface or the fins, golden shiners (Notemigonus crysoleucas) are unique in that infections will localize in the gill tissues and few, if any, of the parasites will appear on the fins or body proper.

The disease is highly seasonal and outbreaks occur most frequently in the spring when water temperatures first begin to rise. The parasite becomes active when water temperatures approach 60°F (15°C), but its optimal temperature range for development is 70 - 75°F (21 - 24°C)(Parker, personal communication). At this temperature range, maturity is reached in three to four days. Butcher (1947) indicates that the cycle may require 11 - 13 days at temperatures from 60 - 62°F (15 - 16°C), while Wolf (1938) has found that the parasite may require upwards of five weeks for development at temperatures near 52°F (11°C). Elevated temperatures adversely affect the survival of Ichthyophthirius and Van Duijn (1956) reports successful treatment by raising and lowering the temperature between 75° and 90°F (24° to 32°C). According to this report the cysts are able to withstand the upper level but with a drop in temperature to the optimal range, most tomites will emerge and these will then be killed when the temperature rises.

Effective control of the disease is dependent upon early detection and prompt treatment. Chemicals which perform well in one area of the country are ineffective in another, primarily due to differences in water chemistry. Fish culturists throughout the country have selected chemicals upon which they rely, but most of them admit to considerable difficulty in controlling ichthyophthiriasis. A summary of the various treatments reported for the disease is provided in Table I.

Currently a great gap in our knowledge exists concerning various strains of this parasite. Only one species has been described for the genus, yet wide differences exist in the virulence of organisms derived from various hosts. For example, a strain obtained from goldfish is usually highly lethal to goldfish and most other species of fish. A culture obtained from a catfish source, on the other hand, may be virulent only towards catfish and goldfish may completely resist infection.

Table I

Suggested treatments for ichthyophthiriasis

Chemical	Dosage	Treatment schedule	Reference
Formalin	200 ppm	Daily - 1 hour	Meyer and Collar, 1964
	250 ppm	Daily - 1 hour	Hoffman, 1959; Davis, 1956
	15 ppm	Single treatment for pond fish	Allison, 1957
Malachite green	0.1 ppm	Not given	Beckert and Allison, 1964
	1.25 ppm	Daily - 30 minutes	Johnson, 1961
Copper sulphate	0.5 ppm	Weekly in ponds	Bishop, personal communication
Mercuric acetate (PMA)	2 ppm	Daily - 1 hour	Clemens and Sneed, 1958
Methylene blue	2 ppm	Daily	Van Duijn, 1956
Sodium chloride (salt)	7000 ppm	Several days	Bauer and Uspenskaya, 1963
	2.0%	Daily - 1 hour	Butcher, 1947
Acriflavin	10 ppm	3 - 20 days	Schäperclaus, 1954
Trypaflavin	10 ppm	3 - 20 days	Bauer, 1961
Quinine hydrochloride	20 ppm	3 - 20 days	Bauer, 1961 Van Duijn, 1956
Atabrine	1 ppm	Daily	Van Duijn, 1956

Other areas in which additional information is needed concerns the development of immunity in fish following infection. The period of time required and the degree of protection which may be afforded are unknown. Hoffman (personal communication) has found a limited immune response in bluegills following their recovery from a moderate infection. Beckert and Allison (1964) reported that white catfish which had recovered from the disease showed an increased resistance to subsequent infections. Fish held at 78°F (25°C) were refractile and fish held at 54°F (12°C) developed only mild infections. Further studies should indicate if vaccination programs might help the fish develop an artificial immunity to carry them through likely periods of infection.

6.2 External protozoans

The unique life cycle involved in Ichthyophthirius infections warranted discussing that disease separately. Most of the other external parasites have few, if any, resistant stages and treatment for such forms is more effective. Trichodina, Chilodonella, Costia, Trichophrya, Scyphidia, and Epistylis are all potential threats to fish survival, either due to their pathogenic activity or to mechanical obstructions which may result from their presence. Chilodonella, Trichodina, and Costia are particularly dangerous to fry and small fingerlings. Loss of appetite which accompanies such infections may prove fatal to very young fish, notwithstanding the damage done by the feeding activities of these organisms.

Treatments for this group of parasites are varied and many are successful. Pond treatments with 15 to 25 ppm formalin have yielded excellent results (Allison, 1957a), though a number of workers have reported difficulties with the use of formalin under certain conditions. Allison (personal communication) has cautioned against the use of this chemical in ponds having a heavy plankton bloom. In his opinion, the sudden death and decay of the plankton populations may cause severe oxygen depletion. Helms (1961) reported that a reduction in dissolved oxygen occurred following the addition of formalin even in distilled water. Allison (personal communication) suggested the use of potassium permanganate to help offset the oxygen-depleting effects of the formalin. We have found that the use of formalin presents no hazard to fish survival unless pond conditions are already septic or the dissolved oxygen is already at a low level. We prefer to drain the pond partially prior to applying formalin and then pump it back to capacity 24 hours after treatment. This technique has been used repeatedly without a single case of oxygen depletion.

Many field workers report that the standard recommendation of 1:4000 ppm formalin for one hour (Davis, 1956; Fish, 1940) has proved lethal to fish in their installations. This condition was also found to be true at our station. Fish suffering from a heavy infestation of Ichthyophthirius or external parasites are generally unable to tolerate concentrations of this strength. If left for the full one hour, many fish will die immediately and the remainder may die within the next 48 hours. To overcome this obstacle, we have found it advisable to keep the fish under continuous observation during the initial few treatments. As soon as the fish begin to show signs of distress by "piping" at the surface, the formalin is removed and the fish are placed in clean, fresh water. During the initial application, the fish may tolerate the chemical for only 10-15 minutes. On the following day, the fish may be re-treated and usually the interval of tolerance will have increased markedly (perhaps due to a partial reduction of the parasites). By following the technique described for the initial application, the fish gradually become adjusted to the desired level of formalin and by the fifth day they will tolerate the compound for extended periods.

Other chemicals which receive extensive use for the control of external protozoan parasites in ponds are copper sulphate, potassium permanganate and malachite green. Tank treatments include the use of potassium dichromate, pyridyl mercuric acetate (PMA), atabrine, and acriflavin. Levels used are similar to those reported in Table I.

Difficulties in culturing and maintaining many of these organisms have limited research on their control. Frequently, removing infected fish from the pond environment to aquarium conditions is enough to effect a "self-cure". An understanding of the inter-relationship between environmental conditions, the parasite physiology, and its host's physiology would lead to more efficient methods of combatting these diseases.

Taxonomic problems are not as serious in combatting this group of organisms as in diseases of bacterial origin, but much ground remains to be covered in this area too.

6.3 Internal protozoans

An increased awareness during recent years has generated considerable interest in the internal protozoan parasites of warm-water fishes. Reports of myxosporidian parasites of warm-water fishes are becoming increasingly numerous. This increase in incidence may be due to a variety of factors; more careful identification, better trained observers, or it is possible that the increased intensive culture of fish is leading toward the development of epizootics due to this group of organisms. To date, the impact of such infections on the vitality or survival of warm-water fishes remains enigmatic. The observations of Lewis and Summerfelt (1964) indicated that Myxobolus notemigoni, a parasite of the golden shiner, did not cause debilitation. However, observations by Sneed (personal communication) indicate that infections may be so heavy on the gills of fry and fingerling channel catfish that it would be unlikely for the parasite not to adversely affect the fish. I have examined a number of mortalities in fingerling channel catfish in which the only symptom of disease found was a very high incidence of cysts of Henneguya sp. in the gill tissue.

Microsporidians are being recognized as pathogens of fish and have been implicated in epizootics on several occasions. Plistophora cepedianum has been implicated in massive kills of gizzard shad (Dorosoma cepedianum) and sterility of the adult fish may have been caused by infections of this parasite (Putz, 1964). Summerfelt (1964) reported that Plistophora ovariae reduced fecundity of the golden shiner and probably produced sterility in older fish.

Controls for both Myxosporidia and Microsporidia are unknown. Knowledge concerning their life cycles, transmission from host to host, and their virulence is very limited. Currently fish producers have been able to ignore these infections and most consider them incidental. However, the implications of such diseases cannot be overlooked as fish culture becomes more and more intensive.

Although a great many more internal parasitic protozoa of warm-water fishes are known, most of them have not been studied in sufficient detail to say more than that they exist.

7 HELMINTH PARASITES

A great many helminths have been identified from American fresh-water fishes and are recorded from waters in nearly every state. Few workers, however, have attempted to assess the influence of these organisms on the health of the fish. With the development of fish farming as a commercial venture and increased production of game fishes by hatcheries, helminth parasites are now being viewed in a different light.

7.1 Monogenea

This group of parasites constitutes the major helminth menace to fish culture in the United States. Gyrodactylus, Dactylogyrus, Cleidodiscus, and a host of others have been recognized as serious problems to fish culturists. It is not the purpose of this paper to enter into a taxonomic differentiation of the various forms which attack our warm-water fishes. A few remarks, however, are in order concerning the way in which infestations of these organisms are manifested. Forms which inhabit the body surface, such as Gyrodactylus, may evoke a variety of symptoms. Some fish will attempt to scratch themselves by scraping the body against any surface in the environment. This response is similar to that induced by penetrating tomites of Ichthyophthirius. Frayed fins, secondary fungus infections, and petechial hemorrhagic areas may be observed in such fish. Other fishes, such as the golden shiner, may congregate in the shallower areas of the pond and may be observed swimming around the margin of the pond in large masses.

Flukes which attack the gill surface, such as Dactylogyrus, may cause destruction of the gill epithelium or loss of blood. Fish infected with this type of monogenean may become anaemic or may exhibit symptoms of anoxia associated with the intense irritation which accompanies the feeding and activity of the helminths.

The control of monogenetic flukes under pond conditions has been successfully achieved by the application of formalin. Lewis and Lewis (1963) recommended the use of 25 ppm for controlling Gyrodactylus elegans. Allison (1957a) recommended 5 ppm formalin as a pond treatment for gyrodactylids but this level has proved ineffective under most circumstances. Potassium permanganate as a pond treatment has also been recommended (Allison, 1957a; Hess, 1930).

Treatments under aquarium or tank conditions include formalin at the concentration of 1:4000 (Clemens and Sneed, 1958; Davis, 1956; Fish, 1940). Special precautions concerning the use of formalin have already been discussed in the section concerning external protozoans.

Further research is needed to develop additional compounds for the treatment of monogenetic flukes in ponds. Apparently, Gyrodactylus sp. is already beginning to show increased resistance to treatment with formalin (Martin,,personal communication). With the continued development of commercial fish farming, the need for better and less expensive chemicals will increase.

The role of these organisms in the transmission of bacterial infections such as hemorrhagic septicemia should be investigated in greater detail. Snieszko and Bullock (1962) implicated Gyrodactylus in this respect and the implication exists that other related forms may function in the same capacity.

The evaluation of many of the less expensive agricultural chemicals, bactericides, or insecticides should be expanded to include this area. As noted above, only two chemicals have been suggested for the treatment of ponds.

7.2 Digenea

Digenetic flukes cause much concern to the American sportsmen and fishery biologists. Much of this concern is generated by the fact that encysted metacercariae, known as "grubs", are obvious even to the untrained eye and a lack of knowledge concerning the organism involved has caused the public to look with apprehension on these forms.

With the exception of producers of bait fishes or ornamental varieties, digenetic flukes have not caused serious problems to the fish culturist. In these species, the unsightly condition resulting from the presence of the encysted larval stages has rendered the individual fish unsuitable for market. The sportsman who encounters a grubby fish will generally discard it as being unfit for consumption. While this is untrue, it does not affect him materially in the sense that it represents a loss of income or in the loss of food urgently needed for his table. The commercial producer of food fishes such as channel catfish will be unable to indulge in such extravagance.

While it is known that, even in nature, peculiar circumstances leading to the development of excessively high parasitemias will cause epizootics, generally such cases are highly localized and are usually temporary in nature. Should the construction of lakes and reservoirs used in the commercial production of fish incorporate physical features favouring the development of parasitic infections of this nature, the effects could be catastrophic. Low or even moderate numbers of metacercariae apparently have little effect on the health of fish. Heavy infections, however, may cause serious problems. Hoffman (1954) reported that extensive mortalities accompanied heavy infections of fathead minnows (Pimephales promelas) with Crassiphialia bulboglossa. Krull (1934) reported similar results and noted definite symptoms of distress in the fish during active penetration by the cercaria.

Van Haitsma (1931) believed that the penetration of diplostomulum-type cercaria caused the death of many fish in lakes where the infection rate was high. Hubbs (1927) found that when very young fish become infected, they tend to retain larval characteristics, show an increase in scale number, and often fail to increase the number of vertebrae as they develop. Hunter and Hunter (1938) noted that infections with metacercariae caused a significant drop in weight. The above observations must be compared with the results of Rabideau and Self (1953) who found that the condition of fish (K factor) is affected more by related factors such as crowding and food supply than by parasitism. It was their conclusion that a fish could support a high parasite burden if all other conditions were optimal; likewise, a low parasitic infection could have a very obvious effect if food were drastically limited.

The impact of larval flukes on the growth and feeding efficiency of cultured fish remains unstudied. The above citations suggest that serious effects might result under unique circumstances but data are needed before any assertions can be made.

Since the normal definitive hosts for the metacercarial forms which occur in fish are attracted by water areas, it is unlikely that it will ever be possible to control such infections through eradication programs. The use of molluscicides, on the other hand, to eliminate the first intermediate host presents some hope. Unfortunately, most of the work in this area thus far has shown that the most effective molluscicides are highly toxic to fish. Kuntz (1956) found that sodium pentachlorophenate was useful in controlling snail vectors of human schistosomiasis but that it was exceedingly toxic to fish. Zectran has been suggested as a possible tool for snail control (Sills, our laboratory) but the margin of tolerance is not great and the toxicity to some species of fish overlaps that of snails. Currently a great many molluscicides are being investigated.

The role of adult flukes which inhabit the digestive tracts of fishes has received little or no attention. Host-parasite studies listing the forms which may be found in fishes are myriad (Van Cleave and Mueller, 1934; Handerlie, 1953; Hugghins, 1959a; Meyer, 1958) and no attempt is made here to list them all. To date, I know of no studies in which this group of helminths has been studied in sufficient detail to make any statements concerning their effects on fish growth and efficiency. The effects of adult digenetic flukes on domestic and wild animals are well documented by Olsen (1947), Macy (1934), Chandler and Read (1961), Noble and Noble (1961) and Morgan and Hawkins (1949). The effects of these helminths on fish should also be examined critically at an early date and, if necessary, means for their eradication or control should be developed.

7.3 Cestoda

Tapeworm parasites of warm-water fishes are generally not given more than a passing glance by fish culturists. One, however, Proteocephalus ambloplitis, the bass tapeworm, is known to cause serious problems in fish culture. Although adults occur frequently and normally in the intestine of the largemouth bass, this stage causes few if any problems. Unfortunately, fingerling bass may also serve as the second intermediate host and in these the plerocercoid larvae fail to encyst as they would in other species of fish. These larvae wander about through the body of the young bass, finally coming to rest in such organs as the gonads, liver or kidney. This migration through the visceral organs results in extensive damage and the resulting fibrous connective tissue frequently envelops the entire abdominal contents in a tight fibrous network. If the number of worms is large, damage to the organs involved is serious and the plerocercoids are known to cause sterility in female bass (Hunter, 1928; Hunter and Hunter, 1929). Should the plerocercoid stage develop in other species of fish, encystment would occur with little or no migration and damage would be minimal. Only when the parasite reaches the required final host in the procercoid stage does the problem arise.

In certain areas of the country, reproduction of the largemouth bass is sharply curtailed due to this parasite (Davis, 1956; Bangham, 1927; Morrison, 1957). In the southern part of the United States the problem has not been serious. Holmes and Mullen (1965) reported no reduction in the apparent successful reproduction of largemouth bass under natural conditions in spite of apparently heavy infections of adult tapeworms in larger bass. If the latter is true, the problem of induced sterility is serious only to the fish culturist who is attempting to raise large numbers of bass fingerlings in a confined area. Since spawning practices for this species require that the adults be allowed to spawn naturally in breeding ponds, inoculation of the fry-rearing ponds occurs whenever the brood fish are infected with adult tapeworms. In such a situation, it is likely that the fry will become infected with procercoid larva. Control of such a situation would require the use of anthelminthic compounds such as di-N-butyl tin oxide as recommended by Allison (1957) or of Kamala (McKernan, 1940) before the adult bass are stocked in the breeding ponds. The latter compound has proved the least satisfactory of the two since administering it has sometimes caused regurgitation. Another technique of control is to kill organisms in infected ponds, destroy adult bass known to carry tapeworms and begin anew with brood stock from a parasite-free source.

Tapeworms of the genus Corallobothrium are commonly found in the intestines of catfish. With the advent of intensive culture of the channel catfish in the United States, the possible effects of this parasite on the feed conversion and growth caused concern. In identical test situations involving 1,500 yearling fish per acre (3,800/ha) both receiving supplemental feed in the form of pellets, wormy fish gained no more than did heavily parasitized fish (our station, unpublished data). Growth, feed conversion, total production and survival were no different in the test groups. Although the treated fish were found to be parasite-free after initial feeding of the anthelminthic, a second treatment was required six weeks later when a check revealed that the parasites were again present in low numbers. While the tapeworms did not appear to adversely affect fish of this size, the impact of heavy infections on fry and small fingerlings should also be considered. During routine diagnostic work at our station, a two-inch (five cm) channel catfish was found to carry 55 maturing tapeworms in its intestine. Such a burden might be expected to adversely affect the growth of the fingerling.

Two large groups of tapeworms commonly infect fish. These are the Proteocephalidae and Caryophyllaeidae and representatives of one of these groups can be found in nearly every cultured species in America. Useful taxonomic information can be found in Wardle and McLeod (1952) or Yamaguti (1959).

7.4 Nematoda

Nematode parasites have received a minimum of attention and one can do little more than note the existence of these parasites in both wild and cultured fishes. Several species of nematodes have been observed on occasions in pond fishes but never in epizootic proportions. The life cycles of most are unknown and few workers have attempted to investigate this group in detail.

Davis (1956) reported that the roundworm, Eustrongylides sp., may be found as a larval stage in the flesh and viscera of many species of warm-water fishes. Yamaguti (1961) reports that this species reaches maturity in fish-eating birds but no life cycles are described. Meyer (1958) and Haderlie (1953) reported finding larvae of Contracaecum spiculigerum encysted in the viscera of many species of warm-water fishes. Raphidascaris, Capillaria, Dichelyne, Haplonema, Hepaticola, Spinitectus, Rhabdochona, and Camallanus represent several of the other genera known to infect American warm-water fishes but none are known to produce problems to the fish culturist.

7.5 Acanthocephala

Fish captured in natural waters frequently will harbor limited numbers of acanthocephalan parasites in their intestines. Others will be found to carry juvenile stages encysted within the fatty tissues among the viscera. Rarely will they be found in adequate numbers to cause serious concern for the health of the fish. While there appears to be local damage to the mucosa and submucosa in the immediate areas of attachment, no extensive damage results from most infections.

A number of species have been reported from American warm-water hosts including Neoechinorhyncus, Leptorhynchoides, Pomphorynchus, and Octospinifer (Van Cleave and Mueller, 1934; Haderlie, 1953; Meyer, 1954; and Hugghins, 1959a). The life cycles of few are known but that of Leptorhynchoides thecatus has been determined (DeGiusti, 1949).

Currently, no one has found it necessary to treat for Acanthocephala in fish but it would seem feasible to attempt removal with anthelminthics such as those suggested for cestodes.

8 MOLLUSCA

Larvae of clams belonging to the family Unionidae spend a brief part of their early life as parasites of fresh-water fishes. These glochidia may be found on the gills or fins of many species of fish in natural waters but they seldom present a health hazard to the fish. Heavy infections may occur in hatcheries which draw their water supply from lakes and streams. The presence of numerous adult clams in the area of the water intake would introduce thousands of glochidia into hatchery ponds. Such a situation might produce a problem to the fish culturist due to the extreme parasitism that could result. Such a situation is described by Davis (1956) in a trout hatchery in California. Currently I know of no cases involving warm-water fishes but the probability of such a development exists.

Disease problems associated with glochidia may be of several types. Extreme cases of parasitism may cause mechanical obstruction of the circulatory system and interference with the respiration of the fish (Murphy, 1942). The lesions caused by the emergence of the larval clams may serve as sites of secondary infection by bacteria or fungi but problems of this nature have been minimal.

During the normal operation of a hatchery, ponds are usually allowed to dry thoroughly at the end of each growing season. Many fish culturists will till the soil while it is dry to help control disease and parasite problems as well as to improve the physical features of the pond. Such a practice will effectively eliminate clams from the rearing ponds. If clams are found in the water supply system, it may be necessary to change the source of supply or move the intake to an area where water can be drawn from a level well above the bottom. Filters of sand and gravel can be used to remove the glochidia but these present problems of maintenance and construction.

9 HIRUDINEA

Leeches have not proved to be a serious problem to date. Occasionally, in natural waters, they may become abundant to the extent that fish life is threatened (Rupp and Meyer, 1954). Leeches are sometimes encountered in hatcheries attached to the fins or body of brood stock fishes. Myzobdella (Illinobdella), Piscicola, Cystobranchus, Macrobdella, Placobdella, and Theromyzon may be found on fish (Mathers, 1948). Meyer (1954) also lists Actinobdella and Piscicolaria as fish parasites. For taxonomic assistance, the reader is referred to Meyer (1940; 1946) and Mathers (1948).

Control (if desired) usually constitutes manual removal of the organisms with forceps or the use of dips in strong salt solutions. Reichelt (personal communication) indicates that 0.5 ppm Dylox effectively removed leeches from fish held in display aquaria.

Although the premise remains unproved at this time, leeches should be considered suspect as possible vectors for other, more serious, diseases of fish. Snieszko and Bullock (1962) reported finding Aeromonas liquefaciens in the digestive tract of leeches and suggested that they may be instrumental in the transmission of hemorrhagic septicemia. Leeches are known to be vectors of trypanosmes in amphibia and reptiles (Kudo, 1960) and their possible role in the transmission of such organisms or related forms (Cryptobia sp.) should be investigated.

10 PARASITIC COPEPODA

Few, if any, groups of parasites cause greater economic losses to the American fish farmer than parasitic copepods. Lernaeid and argulid parasites of minnows and goldfish cause extensive losses annually due both to mortality and to disfigurement which renders the grown fish unsuitable for market.

Lernaea cyprinacea, in particular, presents the most serious problem due to its apparent lack of host specificity (Tidd, 1934; Uzmann and Rayner, 1958; Putz and Bowen, 1964; Hugghins, 1959b). Although scaled species are most susceptible, smooth-skinned fishes such as catfish are also vulnerable to attack. Sites of attachment are usually accompanied by acute hemorrhagic reactions which frequently become foci for secondary infections by bacteria or fungi. Infestations due to L. cyprinacea may evoke a variety of behaviour patterns from fish. If the parasites are attached near nerve centres such as the brain or along the lateral line, infested fish frequently will swim in a tight circle or exhibit convulsive movements when frightened. Heavily infested fish quickly lose stamina and may suffer loss of balance, frequently swimming upside down or hanging vertical in the water in a moribund condition. According to Putz and Bowen (1964) the parasites cause hemorrhage, ulcerous wounds, retardation of growth, loss of weight, changes in the numbers of blood cells and death. The life cycle as described by Putz and Bowen (1964) requires 18 days at temperatures between 23° and 30°C. Lahav and Sarig (1964) indicate an 18-22 day life cycle at 25°C.

Treatment for infestations of Lernaea is usually accomplished through the application of insecticides to the waters at levels below the lethal dosage to fish. Benzene hexachloride (hereafter referred to as BHC) was among the first chemicals to be used for the treatment of copepods on fish (Giudice, 1950) and it remained a standard remedy until about 1963 when consideration was given to the possible use of organophosphate insecticides. Stevenson (1954) had shown that parathion was a potential control but hazards to human health prevented its extensive use. Problems encountered with various formulations of BHC and with adverse side-effects (Meyer, 1963; 1966) led to a search for better chemicals for use in the control of Lernaea cyprinacea. Shilo et al., (1960), Lewis (1961), and McNeil (1961) all encountered difficulties with the use of benzene hexachloride or its purified isomers. Increased resistance to treatment with BHC has been shown in the case of Argulus sp. (Lahav et al., 1962) and apparently similar responses have been shown by L. cyprinacea (Martin, personal communication). Ponds with a history of BHC usage required additional treatments or higher levels than ponds in which the chemical was used for the first time.

When used, BHC is applied in the form of a 12 percent wettable powder at the rate of 1.35 pounds (0.6129 kg) per acre foot (12/9.68 cu.m) at five-day intervals for one month (Meyer, 1963). McNeil (1961) has suggested the use of 5.0 ppm Lindane (99 percent gamma isomer of BHC) for sterilizing hatcheries with problems due to Lernaea. Methyl parathion is applied at the rate of 0.125 ppm (active ingredient) per acre foot (1219.68 cm) at five-day intervals until control is achieved. Potassium permanganate at levels up to 25 ppm was used by Shilo et al., (1960) for the removal of adult lernaeids from carp in a tank treatment. Such high levels of potassium permanganate are toxic to most fish in our area. Clemens and Sneed (1959) reported that the 24-hour tolerance of channel catfish to the chemical was less than 3.2 ppm. Swingle (1958) has successfully used 4 ppm but cautions against use of higher levels. Additional potential controls for the anchor parasite as listed by Putz and Bowen (1964) include salt as a 3 to 5 percent dip, formalin at 250 ppm for up to one hour, malathion - 0.5 to 1.0 ppm, Neguvon - 0.2 ppm, Dipterex - 0.2 ppm, and Chlorine - 1 ppm for three days.

During recent years, organophosphate insecticides have become increasingly popular for use as controls for L. cyprinacea due to the specificity of their action and their relatively short duration in applied waters (Meyer, 1965a). Lahav et al. (1964) reported the successful eradication of Lernaea from carp ponds in Israel using 0.5 ppm of Dipterex. Meyer (1966) indicated that the use of 0.25 ppm (active) of Dylox was likewise an effective control. It should be noted here that Dipterex, Dylox, and Neguvon all contain the same active ingredient (O,O-Dimethyl, 2,2,2, trichloro-1-hydroxyethyl phosphate) and various names have been assigned by the Chemagro Corporation or Bayer Fabriken according to the formulation and its intended use.

The toxicity of benzene hexachloride to many species of fish has limited its use. Catfish and centrarchids are highly susceptible to poisoning with BHC even though cyprinids and catostomids apparently are tolerant of moderate dosages (Stevenson, 1954; Henderson et al., 1959). Dylox, on the other hand, has been applied on a wide variety of species without adverse results (Hornbeck et al., 1965; Carlson, 1966; Pickering et al., 1962). Malathion is an organophosphate which should receive some further study. Its relatively low toxicity to humans should make it a desirable compound if it will perform well against Lernaea.

Recent concern over the fate of chemicals applied in waters and soils has focused attention on those compounds used in fish culture. A dearth of information concerning the ultimate fate of these chemicals exists. Data are urgently needed to determine if fish are fit for human consumption after treatments for the anchor parasite or others. Long-term effects must also be investigated on the reproduction of offspring resulting from fish treated with chemicals as well as possible repercussions which might result from the accumulation of pesticides in the bottom muds or in aquatic vegetation. To date, I know of only one study in which the effects of feeding a pesticide on succeeding generations have been investigated. Clemens et al. (1966) found that fish on a ration containing 4,000 ppm Dylox showed no adverse effects on growth and reproduction. Additional studies of such nature would be most valuable in selecting the most desirable chemicals for treating diseases.

Lernaea cyprinacea is by no means the only lernaeid parasite of American fishes. According to Putz and Bowen (1964), eight species of Lernaea are known but only L. cyprinacea presents problems of major significance. Harding (1950), Wilson (1917; 1918), and Yamaguti (1963) provide excellent reference material.

The fish louse, Argulus sp., is occasionally responsible for epizootics in natural waters (Allum and Hugghins, 1959). Producers of goldfish report difficulty with this parasite but it has not been a problem to minnow raisers or other fish farmers. At our station one case of Argulus has been identified in the diagnostic laboratory in five years. Treatments for fish lice have not been extensively studied. It is to be presumed that chemicals used for the treatment of Lernaea would also be effective against Argulus but there are few reports of such attempts.

Achtheres sp. and Ergasilus sp. are encountered on wild fishes in many host-parasite studies. Their incidence in such situations is usually low but under unusual circumstances, heavy parasite burdens can develop (Kelly and Allison, 1962; Hugghins, 1959b). I have had occasion to examine specimens from only one fish hatchery, so I feel that these parasites too, are primarily of only academic interest at the present time. Should controls be needed, chemicals currently known to be effective against copepods, i.e. Lernaea, should be tried first.

11 DISEASES NOT CONSIDERED

Diseases known to be due to nutritonal deficiencies have not been considered in this paper. Although work in this area related to warm-water fishes is limited, it is definitely known that nutritional diseases occur. For example, a thiamine deficiency was observed in fingerling flathead catfish being fed a ration of fresh carp flesh and artificial feed (Giudice, 1963).

Disorders due to poisoning with industrial or agricultural chemicals likewise have not been discussed. This area represents an entirely new field and frequently involves subtle changes in the histology of organs or of the blood picture. Many of the pathological conditions associated with poisonings of this nature are not known.

Oxygen depletions (anoxia) due to excessive blooms of algae or due to over-feeding have not been considered. The increased production of food fishes in the United States will lead to an increase in mortalities due to this cause. The conditions leading to such oxygen deficiencies are not discussed here even though catastrophic fish losses may result.

Problems associated with predation by aquatic insects have also been omitted. Generally these organisms are not a problem in a well-managed hatchery, but excessive numbers of eggs of a water boatman (*Ramphocorixa acuminata*) on crayfish (*Procambarus* sp.) under culture at our station was interesting. Although the eggs did not present a problem themselves, their abundance impaired movement and other normal activities of the crayfish (Meyer, 1965b).

Conditions induced by abnormalities in the environment, such as supersaturation of gases in the water supply and the problems presented as well as the symptoms exhibited by the fish have not been discussed. The effects of certain injurious substances in the water supply such as heavy metals, ammonia, or organic acids have also been omitted.

Abnormalities of growth or development have also not been considered. Neoplasms of various types are encountered on fish at infrequent occasions and knowledge of their cause or control is very limited. Currently few, if any, of the tumors or other anomalies have been submitted to qualified pathologists for accurate determinations.

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DISEASES AND PARASITES OF FISHES IN WARM-WATER PONDS IN ASIA AND THE FAR EAST

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IX/R-4

DISEASES AND PARASITES OF FISHES IN WARM-WATER PONDS IN ASIA AND THE FAR EAST

Abstract

Existing knowledge on parasites and diseases of warm-water cultured fishes in Asia and the Far East is surveyed. While several parasites have been recorded, not much is known about the host-parasite relationships, pathology and control methods. Fungal infection, bacterial diseases like fin rot and tail rot, ulcer, dropsy, and eye disease of catla, the red disease of Japanese eel, protozoan and other infections by Monogenea, Aspidoctylea, Digenea, Cestoda, Nematoda, Acanthocephala, Hirudinea and Crustacea, non-parasitic diseases like tumours, asphyxia and a few other miscellaneous diseases of fish are discussed. Control methods have been developed in respect of some of the more serious infections, but standardization is necessary in most cases. It is suggested that in future special emphasis may be laid on control of infections in hatcheries or nurseries, study of bacterial and virus diseases, understanding of the relationship between nutrition and occurrence of diseases and development of disease-resistant strains of fish.

MALADIES ET PARASITES DES POISSONS DANS LES ETANGS A TEMPERATURE ELEVEE EN ASIE ET EN EXTREME-ORIENT

Résumé

Cette communication passe en revue les connaissances actuelles sur les parasites et les maladies des poissons élevés en eau à température élevée en Asie et en Extrême-Orient. Si certains parasites ont été identifiés, on ne sait pas grand chose sur les rapports hôte-parasite, la pathologie et les méthodes de lutte. Diverses infections sont passées en revue: maladies provoquées par des champignons, infections bactériennes comme la pourriture des nageoires et la pourriture de la queue,ulcère, hydropisie, maladie des yeux du catla, maladie rouge de l'anguille japonaise, maladie provoquée par des protozoaires et autres infections dues à des Monogenea, Aspidocotylea, Digenea, Cestoda, Nematoda, Acanthocephala, Hirudinea et Crustacea, maladies non parasitaires comme les tumeurs, l'asphyxie, etc.

Des méthodes de lutte ont été mises au point pour certaines des infections les plus graves, mais dans la plupart des cas la normalisation laisse à désirer. Il est suggéré qu'à l'avenir une attention spéciale soit accordée à la lutte contre les infections dans les frayères ou alevinières, l'étude des maladies à bactéries et à virus, la connaissance des rapports entre la nutrition et l'incidence des maladies et enfin la création de lignées de poissons résistants.

ENFERMEDADES Y PARASITOS DE LOS PECES EN LOS ESTANQUES DE AGUAS CALIDAS DE ASIA Y EL LEJANO ORIENTE

Extracto

Se pasa revista a los conocimientos actuales sobre parásitos y enfermedades de los peces cultivados en aguas cálidas de Asia y el Lejano Oriente. Aunque se han registrado varios tipos parásitos, no se conoce gran cosa acerca de las relaciones entre huesped y parásito, patología y métodos de control. Se examinan en este trabajo la infección por hongos, las enfermedades bacterianas, como la putrefacción de las aletas y de la cola, la úlcera, la hidropesía y las enfermedades del ojo de Catla, la enfermedad roja de la anguila japonesa, las infecciones protozoarias y otras infecciones por Monogenea, Aspidocotylea, Digenea, Cestoda, Nematoda, Acantocephala, Hirudinea y Crustacea, las enfermedades no parasíticas como tumores, asfixia y algunas otras diversas enfermedades de los peces. Se han desarrollado métodos para luchar contra algunas de las infecciones más graves, pero en la mayoría de los casos es necesario normalizarlos. Se propone que en lo futuro se preste especial atención a la lucha contra las infecciones en las piscifactorías o lugares de cría, al estudio de las enfermedades bacterianas y virósicas, al conocimiento de la relación entre la nutrición y la aparición de las enfermedades y al desarrollo de tipos de peces resistentes a las enfermedades.

1 INTRODUCTION

Fish pathology has generally been a neglected field in the Asian and Far Eastern countries, although it is in this region that progress in fish culture has been making rapid strides, creating conditions favourable for fish diseases to occur more frequently and in epidemic proportions. Most of the information so far available on the problem from this area is based on taxonomic studies and it is only in recent years that some attention is being paid, in some of the countries, towards a proper understanding of the infections which either cause, or are likely to cause, damage to cultured fishes or to reduce their market value. The object of this review, however, is to survey existing knowledge on the parasites and diseases of fishes which are either cultivated or are cultivable in the warm-water ponds of Asia and the Far East. Hence the results of pathological as well as taxonomic studies have been taken into account. Species of fishes included in the lists given by Hora and Pillay (1962) and Alikunhi (1957) only have generally been considered, excluding cold-water fishes.

The information presented in this review is derived mainly from results of investigations conducted in countries of the Indo-Pacific region. As regards the Asian part of the Soviet Union, clear demarcation of data collected from warm-water ponds of the area has not been possible. However, a brief note is given separately mentioning some of the important parasites known to affect cultured carps of the zone.

The guiding factors for inclusion of records of parasites have been the species and locality of the host fish. Definite information as to whether the fish was obtained from pond, river or lake is sometimes not available, especially when taken from market. This, however, should not be of serious concern, even though definite records from fish collected from environments other than ponds or tanks have normally been omitted. Also, no attempt has been made to discuss details regarding nomenclature, taxonomic position etc., of the different parasites mentioned, as this is beyond the scope of the present review.

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2 PARASITIC INFECTIONS

2.1 Fungi

2.1.1 General fungal infections

Fungus is known to attack eggs, fry, fingerlings and adults of fishes and as a general rule the infection starts when the hosts get injured either mechanically or as a result of other parasitic infections. *Saprolegnia parasitica* Coker is the most common fungus affecting fishes and is perhaps found in almost all countries where fish cultural practices are in vogue. In India, the incidence of the disease has been observed in major carps[1] cultured in different parts of the country (Gopalakrishnan, 1963; 1964). The fry and fingerlings, when transported over long distances get bruises on the body and unless properly disinfected, these become sites of fungus infection, resulting sometimes in large-scale mortality also. While studying a case of fungus disease on the gourami, *Osphronemus goramy* (Lacépède) Chidambaram (1942) observed red patches on the body of the fish which showed the presence of *Saprolegnia* sp. Records of mortality due to fungus in fry of the murrel, *Ophiocephalus marulius* Hamilton Buchanan, are also available (Khan, 1922). The infection appears to have been observed also on the milkfish, *Chanos chanos* (Forskal) in the Philippines, although very occasionally only (Rabanal *et al.*, 1951). Fungal infection is rare in the ponds of the Tropical Fish Culture Research Institute, Malacca though *Saprolegnia parasitica* and *S. ferax* (Gruith) have been observed as secondary infections on a few damaged fish brought for examination (Prowse, personal communication).

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[1] *Catla catla*, *Labeo rohita* and *Cirrhina mrigala*

Maximum information about fungus diseases occurring on warm-water fishes in the Indo-Pacific region appears to have been obtained from Japan, where detailed investigations have been conducted on the infections in eel culture ponds (Hoshina, 1959; Egusa, 1965). The disease, locally known as "sure", affects the Japanese eel, Anguilla japonica and has been reported to cause severe losses in recent years. Generally healthy fish are resistant to fungus, primary injuries caused by different factors being the real zones of attack (Egusa, 1963). Recent experimental observations made by Egusa (1965) have indicated that probably fungus is a secondary infection and a bacterial disease is the primary cause. Further developments in this line are awaited. The fungus responsible for the disease is Saprolegnia parasitica and the chief regions of the body affected are the head and tail (Hoshina and Ookubo, 1956; Hoshina et al., 1960). The main symptoms of the infection are: the fish become weak and lethargic and gradually die after ulceration or exfoliation of the skin followed by hemorrhage, exposure of jaw bones, blindness, congestion at the base of pectoral or anal fins, inflammation of the liver and intestine, etc. The pathological lesions show the presence of pseudomonads. Bacilli have been isolated from heart, spleen, kidney and liver of infected fish. Achlya racemosa Hildebrand, Aphanomyces stellatus deBary, Saprolegnia ferax (Gruith) and S. parasitica have been found to be capable of infecting the fish under experimental conditions. The life cycle, pH suitable for growth and resistance against various chemicals, of Saprolegnia spp. isolated from infected eels and fish eggs have also been studied (Arasaki et al., 1958a, b).

The popular treatments adopted against fungus infections in the region under review are baths in 3 percent common salt solution, 1:2,000 or 1:3,000 copper sulphate solution or 1:1,000 potassium permanganate solution, till the fish show signs of distress (Hora and Pillay, 1962; Gopalakrishnan, 1963). Khan (1922) reported 78 percent reduction in casualities of fungus-infected murrel fry when the live car in which they were transported was smeared with salt and washed in clear water. Data on the resistance of Saprolegnia infected eels in Japan to malachite green, potassium permanganate, formalin, copper sulphate, etc., are available (Hoshina and Ookubo, 1956; Hoshina et al., 1960) and control methods based on these may yield interesting results. Different experiments on the use of malachite green in curing Saprolegnia infection have been conducted with satisfactory results (Noguchi and Kakumina, 1958). Arasaki et al., (1958b) found that the eels may be treated with 0.2 ppm malachite green to get rid of fungus infections. For eggs of the common carp Cyprinus carpio Linnaeus and goldfish Carassius auratus Linnaeus, treatment with dilute sea water of specific gravity 4.0 and 5.0 respectively is recommended by Nakamura (1962).

2.1.2 Gill fungus

Gill rot caused by the fungus Branchiomyces sp. is reported to be common on cultivated fishes in ponds having abundant decaying organic matter (Hora and Pillay, 1962), but it appears that specific investigations on the problem have not yet been attempted in the Indo-Pacific region. In view of the serious nature of this disease, which produces rotting of the gills due to obstruction of blood vessels, it would be worthwhile to take up comparative surveys and field investigations on the problem.

The general control methods advised against gill rot are: introduction of cool water, prevention of pollution, stopping of artificial feeding, addition of lime, etc. (Hora and Pillay, loc. cit.). In case of limited infections, baths in 3 to 5 percent common salt solution for five to ten minutes are also tried (Alkunhi, 1957). More specific studies are necessary for evolving control methods against this disease.

2.2 Bacteria

2.2.1 Fin and tail rot

This disease has been observed for a long time by fish culturists in the region under review. To begin with the disease is noticed as a white line on the margin of the fin which eventually spreads towards the base, resulting in disintegration and putrefaction. The disease affecting fingerlings of Osphronemus goramy which were being transferred from a

Madras Fish Farm was described by Khan (1939), who suggested that overcrowding, and dirty muddy water, aggravated the spread of the disease. The infection has been found to affect fry, fingerlings and adults of major carps in different parts of India (Gopalakrishnan, 1963). A case of epidemic fin rot in *Chanos chanos* has been reported by Rabanal *et al.*, (1951), but the same did not recur after proper disinfection and isolation. Much more remains to be known about this disease, especially the pathological changes.

It may be very difficult to save fish showing advanced stages of fin and tail rot. However, control during the earlier stages has been achieved, using mainly copper sulphate solution. Khan (1939) used 1:20,000 solution for 10–15 minutes to treat infected gourami. Fingerlings of the rohu, *Labeo rohita* (Hamilton Buchanan) have been cured using 5.0 ppm solution followed by a bath in 3 percent common salt and mortality in some ponds was checked with 0.5 ppm group treatment (Calcutta, 1955). The author has been using 1:3,000 strength for one minute dips (Gopalakrishnan, 1963). However, more efficient methods are required for combatting this infection.

2.2.2 Ulcer disease

The present author has come across a bacterial ulcer disease affecting the major carps in India (Gopalakrishnan, 1963). The chief symptom of the disease is the presence of open sores or ulcers on the body of the fish which increase in size gradually, exposing the muscles. Detailed investigations on this disease are in progress.

Pending evolution of suitable control methods against this ulcer disease, dip treatment for one minute in 1:2,000 copper sulphate solution for three to four days, is being advised.

2.2.3 Dropsy

Infectious dropsy among cultured major carps in India has been reported during certain seasons, especially in late winter (Barrackpore, 1960a, b). The etiological agent is a species of *Aeromonas* and by inoculating a pure culture of the bacteria, the disease has been experimentally produced on fingerlings of the catla, *Catla catla* (Hamilton Buchanan), rohu *Labeo rohita* (Hamilton Buchanan), and the mrigal, *Cirrhina mrigala* (Hamilton Buchanan) (Gopalakrishnan, 1961a). The symptoms observed are more or less similar to those described in European countries.

Thorough disinfection with 1 ppm potassium permanganate solution or dip treatment in 5 ppm of the same chemical have been found to be partly effective in checking spread of the disease (Gopalakrishnan, 1963).

2.2.4 Eye disease of catla

An epidemic eye disease affecting medium-and large-sized catla has been studied in detail by the author (Gopalakrishnan, 1961b). The infection affects the eyes, optic nerves and brain of the fish and causes large-scale mortality. During the initial stages, the cornea of the eye becomes vascularized and later on it becomes opaque. Subsequently, the eye ball gets putrefied, leading to death of the fish. The etiological agent is a variant of the bacterium *Aeromonas liquefaciens* (Beijerinck).

Fish affected badly with the eye disease rarely recovers, but during the early stages of infection hourly baths in 8–10 mg/litre Chloromycetin, given on three consecutive days, have given good cures. Prophylactic treatment with potassium permanganate (1 ppm) and provision of high dissolved oxygen content in the medium are helpful in checking the spread of the disease (Gopalakrishnan, 1961b; 1963).

2.2.5 Red disease of Japanese eel

This disease locally known as "hireaka-byo" is a serious cause of trouble in eel ponds of Japan (Hoshina, 1962a). The infection can cause large-scale epidemics and standardized control methods based on the results of the investigations made will be helpful to the eel culturist. The infection is caused by one of the bacteria Aeromonas punctata (Zimmermann) and Parabactrum anguillimortiferum Hoshina or by a combination of the two (Hoshina, 1962b).

2.2.6 Other bacterial infections

Infection by Pseudomonas backis is known to cause "spot" disease of carps in Japan (Tamura, 1961) but details of the same are not available. Recent reports indicate that some of the bacterial diseases in Japanese farms have been controlled, but others are still unchecked (IPFC, 1965).

A disease likely to be bacterial in origin has been found to affect chinese carps1/ of half to one kg weight in Malaysian farms, but studies on the same have yet to be carried out (I.P.F.C.,1962).

The gaps in our knowledge on bacterial diseases occurring in Asia and Far Eastern countries are thus quite wide, as pathological investigations have been possible in a few instances only. More diseases are likely to be present and even about those already known, complete information will have to be gathered with special emphasis on standardization of control methods.

2.3 Protozoa

2.3.1 Ciliata

The white spot disease or ichthyophthiriasis is one of the commonest protozoan diseases observed in fresh-water fishes. In general, the symptoms and pathology of the infection in warm-water pond fishes are similar to those observed in trout hatcheries (Gopalakrishnan, 1965). The causative organism viz., Ichthyophthirius multifiliis Fouquet infects externally on different regions of the body of the fish and causes simple hyperplasia of the epidermal cells around the site of infection causing formation of pustules. In India, the disease has been observed in major carps cultured in different regions of the country (Gopalakrishnan, 1964). Instances of fish mortality due to this infection have been observed especially in nurseries and rearing tanks (Gopalakrishanan, 1963). Fingerlings of the bata, Labeo bata (Hamilton Buchanan) and Cirrhina mrigala have been experimentally infected with this parasite (Tripathi, 1955). Reports from the Ceylon Fisheries Research Station indicate that adults and fingerlings in the nursery ponds in Colombo and Polonnaruwa are affected by the disease in epidemic proportions, usually with sudden changes in weather (Mendis and Fernando, 1962). The disease is prevalent in Malaysian fish farms also (IPFC, 1965). During the course of investigations conducted on the occurrence of the disease in some trout hatcheries of Ballart Fish Acclimatization Society, Victoria, Australia, it was observed that the infection was introduced by infected carps and that among other species of local fishes, Cyprinus carpio and Carassius auratus were affected (Butcher, 1947). A report from Hawaii indicates that in December 1956, 60 specimens of the tilapia, Tilapia mossambica Peters were introduced into the islands from Singapore and that most of them died due to this disease (Brock and Takata, 1955).

Other ciliate infections observed are tabulated below:

Parasite	Host	Locality	Reference
Trichodina indica Tripathi	Different fishes	India	Tripathi (1954)
T. gotoi Ariake	Goldfish, Common carp	Japan	Ariake (1929)
T. pulchra Ariake	-do-	-do-	-do-
T. ehrenbergi Ariake	-do-	-do-	-do-
T. mirabilis Ariake	-do-	-do-	-do-
T. annulata Ariake	Goldfish	-do-	-do-

1/ Ctenopharyngodon idella, Hypophthalmichthys molitrix and Aristichthys nobilis

Parasite	Host	Locality	Reference
Trichodina sp.	Fan-tail goldfish	China	Yin and Sproston (1948)
Trichodina sp.	*Ophiocephalus* sp.	-do-	Sproston *et al.* (1950)
Scyphidia pyriformis Tripathi	Rohu, catla, mrigal and reba (*Cirrhina reba*)	India	Tripathi (1954)
Cyclochaeta spp.	Pond fishes	Indo-Pacific	Hora and Pillay (1962)
C. domerguei Wallengren	Common carp, gourami	Ceylon	Mendis and Fernando (1962)

Generally speaking, disinfecting the pond with salt or quick lime is considered to be very effective against ichthyophthiriasis (Hora and Pillay, 1962). Alternate methods are: treatment with 3-5 percent chloride solution for 30 minutes, 5 percent aluminium sulphate for about one minute or 1:2,500 formalin for 15 minutes. In India, satisfactory results have been obtained with hourly baths in 1:5,000 formalin for 7-10 days, 2 percent sodium chloride solution for more than seven days or 1:50,000 quinine solution for 3-10 days (Gopalakrishnan, 1963; 1964). In Malaysia, reduction in mortalities of fish fry has been achieved by reducing the conditioning period (IPFC, 1965).

Tripathi (1954) found that *T. indica* and *S. pyriformis* were killed in 5 to 10 minutes by 2-3 percent common salt solution, 1:1,000 acetic acid solution and 1:5,000 to 1:6,000 formalin solution. In early stages of *Cyclochaeta* infections, a bath in 1 percent salt solution for 5 to 10 minutes and in advanced cases 3 percent salt solution, 1:500 glacial acetic acid or 1:2,500 formalin solution will be useful (Hora and Pillay, 1962).

2.3.2 Mastigophora

Costiasis produced by *Costia necatrix* Leclerque is the most common mastigophoran infection observed in pond fishes of the region under review (Suzuki, 1938; Hora and Pillay, 1962; Gopalakrishnan, 1964). Other records are given below:

Parasite	Host	Locality	Reference
Bodomonas rebae Tripathi	Mrigal, rohu and catla	India	Tripathi (1954)
Trypanosoma clariae Montel var. *batrachi* deMello et Valles	*Clarias batrachus*	Goa (India)	deMello and Valles (1936)
T. punctati Hasan et Qasim	*Ophiocephalus punctatus*	India	Hasan and Qasim (1962)
T. saccobranchi Castelleni et Willey	*Heteropneustes fossilis*	Ceylon	Fernando (1964)
T. ophiocephali Pearse	*Ophiocephalus striatus*	Siam	Pearse (1933)
T. trichogasterae Pearse	*Trichogaster trichopterus*	-do-	-do-

Control methods tried for costiasis are: bath for about 10 minutes in 1:2,500 formalin solution or 1:500 glacial acetic acid (Hora and Pillay, 1962) and 3 percent common salt solution (Gopalakrishnan, 1964). Tripathi (1954) found that *B. rebae* was killed in 5-10 minutes by 2-3 percent common salt solution.

2.3.3 Sporozoa

Myxosporidians which are typical fish parasites are known to occur in the entire Asia-Far East region. The parasites produce cysts on different regions of the body and in internal tissues and organs. When large numbers of cysts are present on the gills, the breathing of the fish is adversely affected. They may also produce prominent hyperplasia forming tumours, hyperplasia of gill epithelium, etc.

Several species of Myxosporidia of the genera *Leptotheca*, *Chloromyxum*, *Myxobolus*, *Henneguya*, *Unicauda*, *Thelohanellus*, *Myxidium*, *Zschokkella*, *Mitraspora*, *Sphaerospora*, *Lentospora*, etc., have been found to infect cultured fishes of the region (Fujita, 1912; 1929; Ishii, 1915a, b; Kudo, 1919; Nakai, 1926; Sikama, 1938; Tripathi, 1952; Hoshina, 1953; Hoshina and Hosoda, 1957).

Chakravarty (1939) found that in mrigal infected with *Myxobolus mrigalae*, the scales from which large cysts had been removed appeared to have been perforated, and that the cysts were formed of an inner fibrous layer and an outer layer produced by the epidermis of the host. The general pathological effects of myxosporidiasis in fish are: weakness, emaciation, raising of the scales along their posterior margins, falling off of scales, loss of chromotaphores, perforation of the scales, etc. (Tripathi, 1952). *Myxidium matsuii* causes serious pathological changes resulting in necrosis, ulceration accompanied by bleeding of the integument, etc. (Hoshina, 1952). The pathological changes caused by *Myxobolus koi* are also known to be very severe resulting in the formation of tumours on gills, destruction of tissues, etc., all of which lead to ultimate suffocation and mortality (Hoshina, 1952).

A very serious epidemic caused by the microsporidian *Plistophora anguillarum* Hoshina, in an eel culture pond in Japan was studied in detail by Hoshina (1951). The parasites were found to produce large number of small whitish cysts in the muscles, disintegration of muscular tissues, swelling of body, etc. In advanced infections the spores were seen in the fascia and sub-cutaneous adipose tissues, as also in the heart, spleen, kidney, liver and intestine, without formation of cysts or causing any pathological changes. In the ruptured tissues, infiltration of lymphocytes, hemorrhage and phagocytosis were also evident in some cases. *Dermocystidium koi* Hoshina et Sahara is another microsporidian found infecting the common carp in Japan (Hoshina and Sahara, 1950).

Myxosporidian cysts are not easily affected by chemical treatment. Hoshina (1952) conducted some experimental studies on this problem, but the results were not satisfactory. The observations of Basu (1950) that the myxosporidian infections observed by him in Indian carps generally were only in waters having less than 400 ppm chloride content, may be significant in designing fresh investigations. Sarkar (1946) found fingerlings of *Cirrhina mrigala* obtained from a fry market in Calcutta, India, heavily infected with *Myxobolus mrigalae* and suggested that it would be desirable to disinfect such fry in Candy's fluid or a weak solution of sodium chloride. More experimental evidence will, however, be necessary to standardize this procedure.

Myxosporidiasis sometimes causes very difficult situations for fish culturists. The author has come across very serious infections in nurseries, but the gap in our knowledge on this fish disease is so wide that nothing much could be done to achieve effective cure.

2.4 Trematodes

Many of the trematodes described from the region do not apparently cause much harm. Under changed environmental conditions, some of these parasites might cause considerable damage or reduce the market value of the fish. This is more evident in the case of monogenetic trematodes, which are capable of multiplying in large numbers quickly, due to their simple life cycle.

2.4.1 Monogenetic trematodes

Several of these parasites coming under the genera Gyrodactylus, Dactylogyrus, Neodactylogyrus, Paradactylogyrus, Mizellus, Thaparocleidus, Diplozoon, Wallagotrema, Ancyrocephalus, Ceylonotrema, etc., have been described from the Asia-Far East region, by different workers (Sproston, 1946; Chauhan, 1953; Tripathi, 1957; Gupta, 1961; Gussev, 1963; Yamaguti, 1963a; Fernando, 1964). Among these, dactylogyrids and gyrodactylids are perhaps the most important and have been reported to cause serious infections (Tripathi, 1957; Hora and Pillay, 1962; Gopalakrishnan, 1964). The common symptoms of gyrodactylosis are: fading of colours, drooping of scales, excessive mucus on caudal peduncle and fins, peeling of skin etc. When the infection is on gills, it is likely that death results from hyper-secretion of mucus on gill surfaces, brought about by irritation (Yin and Sproston, 1948). Dactylogyrids have also been found to be very harmful; they feed on blood in the thin capillaries of the branchial region (Jain, 1959).

Only little is known regarding control of these parasites. Tripathi (1957) found that alternate baths with 1:2,000 acetic acid solution and 2 percent sodium chloride solution were effective, under laboratory conditions against infection by Gyrodactylus elegans indicus on major carp fry. In the case of adult fishes, dip treatments for five minutes in 5 percent common salt solution and 1:5,000 formalin have given encouraging results (Gopalakrishnan, 1964). It has also been suggested that during epidemics, badly affected fishes may be destroyed and mild infections treated for half an hour in 1:100,000 potassium permanganate solution or 1:2,500 formalin (Hora and Pillay, 1962). Yin and Sproston (1948) found that Neodactylogyrus bini and N. anguillae infecting Anguilla japonica in China, showed a sustained adaptability to sodium sulphate up to about 1.5 percent concentration and also that the parasites were more resistant than the host fishes to high temperature. During preliminary trials, 2 ppm Dipterex has been found to be useful for control of Dactylogyrus sp. (Prowse, personal communication).

2.4.2 Aspidocotylea

Aspidogaster Yimai Kawamura infecting Cyprinus carpio in Japan, and A. piscicola Rawat in the intestine of Labeo spp. in India, are examples of parasites coming under this group, recorded from the region under review (Yamaguti, 1963a).

2.4.3 Digenetic trematodes

Among the digenea recorded from cultivated species of pond fishes of the Indo-Pacific region, a few only have been found to cause serious harm. A large number of these parasites have, however, been studied, but due to shortage of space, they are not listed here. (See Southwell, 1913; 1915; Vazquez-Colet and Africa, 1938; 1939; Tang, 1941; Abraham and Anantaraman, 1955; Singh, 1956; 1959; Long and Lee, 1958; Long and Wai, 1958; Martin, 1958; Velasquez, 1958; 1959; Yamaguti, 1958; Agarwal, 1959; 1962; Dollfus, 1959; Coil and Kuntz, 1960; Saksena, 1960; Srivastava, 1960; Miyazaki, 1960; Gupta, 1961; Mehra, 1961; Ganapati and Rao, 1962; Kamo et al., 1962; Chung-chang et al., 1963; Agrawal, 1964; Chun, 1964; Pande et al., 1964; Rai and Pande, 1965).

No serious attention appears to have been paid yet to understanding the pathology and control of digenetic trematodes in warm-water pond fishes. The black-spot disease produced by Diplostomum spp., Diplostomulum spp. etc., is known to be prevalent in some rearing and stocking ponds and further studies in this direction will be of value. The information available on the life histories of the parasites will be helpful in formulating biological control methods. Isolating the infected specimens and giving them dip treatment in 3:100,000 picric acid for a period of one hour has been successful in controlling the disease in some instances (Gopalakrishnan, 1963).

2.5 Cestodes

Tape worms of the genera Caryophyllaeus, Lytocestus, Djombangia, Khawia, Bothriocephalus, Senga, Gangesia, Digramma, Ligula etc., have been found to infect warm-water pond fishes of the Asia-Far East region (See Southwell, 1930; Pearse, 1933; Yamaguti, 1959; Furtado, 1963; Fernando, 1964).

Very little is known about the pathological effects produced by these cestodes. In fish infected with *Ligula intestinalis* (Linnaeus) the abdomen is enlarged, and in advanced cases, the parasites in the body cavity may break the body wall (Gopalakrishnan, 1964). An instance of fish mortality due to cestode infection in a tank at Nagpur, India, has been reported by Chauhan and Ramakrishna (1958). The infected fishes appeared dull, sickly, and with parts of the alimentary canal swollen or completely choked by hundreds of cestode cysts. The gall bladder was also affected in some cases.

The endoparasitic nature of the infection and lack of opportunities have perhaps contributed to the dearth of information on the pathology and control of tape worms in pond fishes. Biological control methods have been tried against *Ligula* infection in some big reservoirs in India (Gopalakrishnan, 1964), but the same methods may not be suitable in ponds.

2.6 Nematodes

Nematode infections are not uncommon in pond fishes of the region, but the presence of a few parasites in large fish may not be of much harm. Only when the number of worms increase considerably, or when they infect fry and fingerlings, is there cause for alarm. Parasites coming under the genera *Camallanus*, *Neocamallanus*, *Paracamallanus*, *Procamallanus*, *Cucullanus*, *Indocamallanus*, *Indocucullanus*, *Heliconema*, *Proleptus*, *Pingus*, *Rhabdochona*, *Spinitectus*, *Philometra*, *Philometroides*, *Spiroptera*, *Agamofilaria*, *Eustrongylides*, *Hedruris*, *Zeylanema*, etc., have been described from pond fishes of the region (Pearse, 1933; Agarwal, 1958; Gupta, 1959; Ali, 1960; Yeh, 1960; Yamaguti, 1961; Chakravarty *et al.*, 1963; Pande *et al.*, 1963; Fernando, 1964; Sen, 1965). Investigations on the pathological effects produced by nematodes will be of interest.

2.7 Acanthocephala

During a recent survey of the parasitic infections in some cultured fishes of India, it was found that 95.3 percent of catla, 76.74 percent of rohu and 7 percent of mrigal examined were infected with *Acanthogyrus acanthogyrus* Thapar (Barrackpore, 1964). Sixty percent of *Ophiocephalus striatus* and 20 percent of *O. punctatus* studied were also found to be infected with *Pallisentis nagpurensis* (Bhalerao). During an earlier investigation, Tripathi (1956) did not find any appreciable pathological effects of the parasites studied by him, but this may not be true in all cases, since it is known that these parasites generally cause injury to the intestine of the host fish.

Acanthocephala of the genera *Neoechinorhynchus*, *Acanthogyrus*, *Pallisentis*, *Acanthocephalus*, *Pararhadinorhynchus*, *Arhythmorhynchus*, *Rhadinorhynchus*, *Mehrarhynchus*, *Centrorhynchus* etc., have been found to infect warm-water pond fishes of the region (Pearse, 1933; Tripathi, 1956; Nadakal, 1963; Yamaguti, 1963b; Barrackpore, 1964; Fernando, 1964).

2.8 Hirudinea

Only meagre data are available on leeches infecting fresh-water fishes of the region. Following are the most important records:

Parasite	Host	Locality	Reference
Leeches	*Labeo rohita*	Bengal (India)	Southwell (1915)
Piscicola spp.	Fishes	India, Burma, Ceylon (?)	Harding and Moore (1927)
Hemiclepsis marginata	Carps	W.Bengal (India)	Saha and Sen, (1955)
Leeches	Mrigal and rohu	W.Pakistan	Khan (1944)
Trachellobdella sinensis Blanchard	'Tsi' fish	China	Moore (1924)
Placobdella undulata Harding	*Etroplus suratensis*	Ceylon	Mendis and Fernando (1962)
Leeches	Fishes	Kashmir (India)	Bhatia (1958)

Attempts to control leech infestations have been made only in few instances. Khan (1944) reported that dips in 1:1,000 solution of glacial acetic acid and disinfection with 1:10,000 potassium permanganate solution killed all the leeches at the Lyallpur tanks. Saha and Sen (1955) found that a single treatment with 5 ppm Gammexane cured most major carps infected with leeches, in a sewage irrigated fishery, and that a second treatment eradicated all the parasites. A popular control method is dip treatment in 2.5 percent common salt solution for about 30 minutes (Gopalakrishnan, 1963). With this, the parasites may only get detached from the body of the host. If possible, it would be advisable to dry the heavily infested ponds.

2.9 Crustacea

2.9.1 Copepoda

Several instances of argulosis associated with fish mortality have been reported from Indian ponds (Hora, 1943b; Calcutta, 1955; Barrackpore, 1960a; Gopalakrishnan, 1963). Sometimes even though mortality may not take place, the infected fish become very weak and emaciated (Gopalakrishnan, 1964). The common pathological effects produced are: stunted growth, loose scales and red spots at sites of puncture. Aquarium observations have indicated that when the parasite makes a fresh attachment, the fish may get 'perturbed' and move either faster or in an irregular manner (Vasisht, 1959).

Different species of argulids have been found to infect cultured fishes of the region and some of the more important records are listed below:

Parasite	Host	Locality	Reference
Argulus siamensis Wilson	*Cirrhina* sp.	Bangkok	Wilson (1924)
	Labeo rohita	India	Ramakrishna (1951)
A. indicus Weber	Fighting fish	Siam	Wilson (1927)
	Ophiocephalus punctatus	India	Ramakrishna (1951)
	O. gachua	-do-	Malaviya (1958)
A. giganteus Ramakrishna	-	-do-	Ramakrishna (1951)
A. bengalensis Ramakrishna	-	-do-	-do-
A. siamensis peninsularis Ramakrishna	-	-do-	-do-
A. foliaceus Linnaeus	-	Ceylon	Mendis and Fernando (1962)
A. japonious Thiele	-	Japan	Tokioka (1936b)
Huargulus chinensis Yü	*O. argus*	China	Yü (1939)

Argulosis is prevalent in Malaysian farms, as will be seen from the report that grass carp (*Ctenopharyngodon idella* Valenciennes) obtained by the Tropical Fish Culture Research Institute were infected (Malacca, 1963). In the commercial ponds of Malaya, where animal excreta are used as fertilizer, the fishes are heavily infected with crustacean parasites, including *Argulus* (Prowse, personal communication). The disease is very prevalent in Japan also (Tokioka, 1936a). Although the infection is reported to be rare in Pakistan, an epidemic in the 5 ha Hiran Minar Fish Farm is known to have resulted in mortality of major carps (I.P.F.C. 1963). Khan (1944) had observed *Argulus* attack on *Cirrhina mrigala* in a tank at Lyallpur and stated that at the point of attachment of the parasites, the scales had fallen off in patches exposing the body.

A method generally suggested for control of Argulus is to drain the water and expose the bottom soil to the sun for at least 24 hours and if this is not possible, application of lime at the rate of 0.1 to 0.2 g per litre (Hora and Pillay, 1962). Fish farmers in India used to attempt control of Argulus infection by capturing the fish and scraping them as clean as possible, allowing frogs to enter into the ponds so that the parasites may be eaten by them or by erecting vertical poles in the water so that the fish may rub their bodies against them, to get rid of the infection (Southwell, 1915). The practice of planting bamboo sticks or posts is very common (De, 1910; Alikunhi, 1957), but as the parasites will not be killed even if they are dislodged, the method does not have any lasting value. Some farmers arrange frequent drag-netting to remove all external parasites (Sen, 1941), but this also may not give any appreciable benefit. Introduction of brackish water and sewage has been found to control the infection satisfactorily (Hora, 1943b). Khan (1944) could combat early stages of the epidemic with a bath of 1:1,000 glacial acetic acid for five minutes, followed by 1 percent salt bath for one hour. Recently, Gammexane has been successfully used in India to control the infection. However, different strengths have been tried and it is necessary to standardize the method. Saha and Sen (1955) reported that they applied two treatments with 0.2 ppm at one week's interval and the parasites disappeared after six weeks. They could cure another infection within 12 days, adopting a 0.1 ppm treatment. However, workers at the Central Inland Fisheries Research Institute had to use Gammexane at 2 ppm strength to control an infection of A. siamensis in catla and mrigal (Calcutta, 1955). The author has obtained good results with two or three applications of W.D.P. Gammexane, which has the advantage of being water soluble, at 0.2 ppm strengths, at weekly intervals (Gopalakrishnan, 1964).

The incidence of argulosis among grass carp at the Malacca farm has been controlled by adding Lindane (15 percent) at a concentration of 8 ml/10,000 litres (Hickling, 1962). Lindane has also been successfully tried at 0.112 ppm i.e., 7 ml of 15 percent Lindane emulsion in 9,092 litres of water (Malacca, 1963). Dipterex (Bayer Diptrex SP 80) at 2 ppm or 80 percent Dimethyl-trichloro-hydroxyethyl-phosphonate, has been found to completely eliminate Argulus on grass carp fingerlings (Prowse, personal communication). Dipterex has also been used in Japan (Kimura, 1960). In China, while sterilization of ponds and introduction of small fishes into the water were the general control methods formerly adopted, some chemical treatments like application of 1:1,000 ammonium chloride solution have also been recommended (Chen, 1933). In Pakistan, when an epidemic took place in the Hiran Minar Fish Farm, Endrin was applied at a strength of 0.008 ppm which killed all undesirable animals (IPFC, 1963).

Lernaeaids are another common source of infection in pond fishes. While only few of these parasites present on the body of a fish may not cause much harm, larger numbers are capable of creating serious situations. Some of the more important records of these parasites are tabulated below:

Parasite	Host	Locality	Reference
Lernaea chackoensis Gnanamuthu	Gourami and catla	India	Gnanamuthu (1951)
L. bengalensis Gnanamuthu	Ophiocephalus punctatus	-do-	Gnanamuthu (1956)
L. cyprinacea chackoensis (Gnanamuthu)	Gourami	Ceylon	Kirtisinghe (1964)
Lernaeocera cyprinacea (?)	Carps	Japan	Ishii (1915c)
Lernaea elegans Leigh-Sharpe	Anguilla japonica; Cyprinus carpio; Carassius auratus, etc.	-do-	Leigh-Sharpe (1925); Nakai (1927); Hu (1948)
L. cyprinacea Linnaeus	Different fishes	-do-	Yamaguti (1936); Kasahara (1962)

Parasite	Host	Locality	Reference
L. polymorpha YÜ	Silver carp	China	YÜ (1938)
L. cyprinacea brachycera (YÜ)	Ophiocephalus argus	-do-	-do-
L. c. elegans Leigh-Sharpe) and L. sp.	-do-	-do-	Hu (1948); Sproston et al., (1950)
L. barilii Harding	Carassius auratus	-do-	Yin (1962); Yin et al., (1963)
L. sp.	Silver carp	Hong Kong	Hickling (1962)
L. sp.	Carassius sp.	Tonkin	Chevey and Lemasson (1936)

Lernaeaids are frequently met with in Japanese fish farms (Tamura, 1961). Details of the infection in the mouth of Anguilla japonica from the Piscicultural Station at Kitagima were studied by Matsui and Kumada (1928). The pathological changes observed were: blood marks on the ventral part of the lower jaw, shrinkage of jaws, congestion of liver and blood vessels on the wall of the body cavity, discolouration and swelling of gall bladder, etc. These authors found that the infection was not present in ponds with water salinity between 1.79 to 7.78 percent. Nakai and Kokai (1931) studied the temperature effects on the life cycle of the parasite and found that the host specificity was very low. Detailed studies on the biology of L. cyprinacea have been made by Kasahara (1962), who found that the infection was common in fresh-water fish farms in the warmer parts of the country, the maximum damage being caused in eel culture ponds. In the carps, generally the female parasite causes mechanical injuries, which may eventually lead to secondary fungal or bacterial attacks. In the eels, the effect is more severe as the location of the parasites inside the mouth affects feeding, growth and respiration of the host, resulting in death. The growth rate of the infected fish has also been found to be very low.

Application of Gammexane at 1.0 ppm concentration in some sewage irrigated tanks in Bengal, India, successfully cured fingerlings of catla from lernaeaids within 24 hours, and without producing any adverse effects on the hosts (Saha et al., 1959). Short baths in 5 percent potassium permanganate solution have given moderately good results (Gopalakrishnan, 1963). When only a few parasites are present, mechanical removal followed by a bath in dilute potassium permanganate solution is generally advised (Alikunhi, 1957). In Japan, immersion of infected fish in 2 percent sodium chloride solution for 15 minutes is a common practice (Nakai and Kokai, 1931). In Hong Kong, local farmers put bundles of castor oil plants in the water to control Lernaea infections (Hickling, 1962). It would be interesting to study the action of the plants on the parasites. Chlorinated tap water has been reported to control the infection on fish fry, observed in Malaysian conditioning tanks (IPFC, 1965).

All the older methods adopted to control Lernaea infections in Japan (Schäperclaus, 1954) have been found to have serious drawbacks by Kasahara (1962), and after experimenting with several insecticides as well as organic phosphorous compounds, he demonstrated that sprinkling Dipterex over the water surface to produce concentrations between 0.2 to 0.5 ppm at least three times at three week intervals, will control L. cyprinacea infection. Three treatments using Dipterex at 0.5 ppm concentration at four day intervals have completely eliminated Lernaea in farms at Malacca also (Prowse, personal communication). Kasahara's (1962) observation that Mesocyclops leuckarti consumes the larvae of the parasite, is of value for evolving biological control methods.

Other important copepod parasites infecting warm-water pond fishes of the region are tabulated below:

Parasite	Host	Locality	Reference
Lamproglena chinensis YU	Ophiocephalus argus	China and Japan	YU (1937) and Yamaguti (1939)
-do-	Anabas testudineus	Thailand	Capart (1943)
L. carassi	Carassius carassius	China	Sproston et al., (1950)
L. chinensis sprostoni Kirtisinghe	Ophiocephalus striatus	Ceylon	Kirtisinghe (1964)
Ergasilus bengalensis Southwell et Prashad	Wallago attu	Dacca (Pakistan)	Southwell and Prashad (1918)
E. hamiltoni , Southwell et Prashad	A. testudineus	Sunderbans (India)	-do-
E. gibbus Nordman	Ophiocephalus gachua	W. Bengal (India)	Karamchandani (1952)
E. batai Karamchandani	Labeo bata	-do-	-do-

2.9.2 Isopoda

Very few isopods have been reported to be parasitic on cultured fresh-water fishes. Shen (1938) described Ichthyonexus geei Boone on Carassius auratus from Soochow and Cyprinus carpio from Peiping; I. formosanus Harada on C. auratus from Taiwan and I. sinensis Shen from body cavity of C. auratus from Peiping, China. Alitropus typus Milne Edwards infest the gill chambers of Wallago attu in Ceylon (Mendis and Fernando, 1962).

2.10 General

Although considerable work has been done in the U.S.S.R. on parasitic infections of cultured fishes, most of the information, in available literature, appears to have been obtained from the European part of the Union. Further, from the accounts available it has not been possible to specify the parasites and infections observed from warm-water ponds in the Asian part alone. Some of the important parasites known to affect cultured carps in the latter zone are: Ichthyophthirius multifiliis, Trichodina megamicronucleata (Dogiel), Dactylogyrus vastator, Gyrodactylus elegans, G. medius, Sanguinicola inermis and Caryophyllaeus fimtriceps Annenkova-Chlopina (Bauer, 1961).

The recent studies of Wang (1963) on prevention of contagious fish diseases in China may also be mentioned. He has suggested some measures to increase survival rate among young fish, viz., disinfection of the pond water with alum or calcium hypochlorite before introducing fish, baths in copper sulphate and calcium hypochlorite solutions, daily disinfection of food and feeding areas with calcium hypochlorite, strict control over quality and quantity of food, etc.

3 NON-PARASITIC AFFECTIONS

3.1 Tumours

Southwell and Prashad (1918) and Mookerjee and Mazumdar (1946) have described tumours in aquarium-reared Anabas testudineus. These were considered as infiltrating neoplasm, malignant epithelioma, colloid carcinoma, etc., but no such growths were found in wild fish. A villous papilloma, structually similar to the human type, was observed by Sarkar and Datta Chaudhuri(1953) in the same species of fish, but from the wild. The same authors have described an osteogenic fibroma found in the connective tissue of Wallago attu collected from a perennial tank (Sarkar and Datta Chaudhuri, 1958). A basophilic tumour has been reported in the pituitary of the cat fish, Mystus seenghala (Sykes) (Sathyanesan, 1962). Except for investigations like these, no serious attention has been paid to the study of atypical cell growths in fishes of this region. This is yet another line for future work.

3.2 Asphyxiations

3.2.1 Gas disease

Under experimental conditions major carp fry up to 20 mm in length have been observed to suffer from 'gas disease or air embolism' under super-saturation of dissolved oxygen (Alikunhi *et al.*, 1951). The symptoms observed were the presence of small bubbles on the lower lip, edges of dorsal fins, caudal fins and stomach. The affected fishes were found to swim at an angle of about 45°, with the head pointing down. Eventually they lost their equilibrium and floated on their sides or upside down. An incidence of gas disease in a public pond at Madura, South India, was studied by Chacko and Job (1948) who found that the affected fish died due to asphyxiation and embolism in the gills and heart. The symptoms observed were 'ragged and tattered' appearance, peeling off of skin, bleeding, presence of gas bubbles in gill filaments, heart, blood vessels, etc., and distension of air bladder.

In Japan, high saturation of nitrogen, above 130 percent air saturation, produces 'gas disease' in fish, resulting in heavy mortality (Matsue *et al.*, 1953; Noguchi, 1954). In the crucian and common carps the disease condition is first observed in the presence of gas bubbles in the fin membrane or accumulation of gas in the orbit, resulting in protrusion of the eye balls (Egusa, 1959). In eels the gas bubbles are generally formed in the head. The ultimate cause of death in all cases is thought to be blocking of blood circulation. Egusa(*loc. cit.*) has experimentally determined the lethal nitrogen limit for young and adult crucian carp, eel and common carp. He found that generally at nitrogen levels below 115 percent of air saturation 'gas disease' did not occur.

3.2.2 Other asphyxiations

Changes in physico-chemical conditions of the environmental medium can cause fish mortality in all situations. Lack of dissolved oxygen, increase in carbon dioxide and production of sulphuretted hydrogen in the bottom soil result in asphyxia (Sewell, 1926; Pruthi, 1932; Khan, 1943; Alikunhi and Ganapati, 1947; Ganapati *et al.*, 1950). High alkalinity (pH 8.76 to 9.55) and the presence of excessive amounts of organic matter also may cause mortality (Mookerjee and Bhattacharya, 1949). During certain seasons, after sudden rainfall or during sultry weather conditions, fishes may come up to the surface of water showing symptoms of 'air hunger' and eventually die (Lin, 1946; Basu, 1958).

3.3 Miscellaneous diseases

Grass carp in Malaya, and milkfish in brackish-water ponds of Java, are sometimes affected by a 'cold' like disease when the temperature of the water drops suddenly with the onset of monsoons (Birtwistle, 1931; Schuster, 1952; Hickling, 1962). The gills of the fish thus affected become white and get covered with mucus. In milkfish the discolouration may disappear after two or three days, when flaps of skin fall off. While grass carp have been reported to die of this disease, no such mortality has been observed in the case of milkfish.

Among other disease conditions reported, fish-dysentry caused by irregular feeding (Hora and Pillay, 1962) and a 'swim bladder disease' of goldfish (Kawamoto, 1961) may be mentioned.

Drugs sometimes produce significant pathological changes in fish. The effects produced in the eye fundus of goldfish have been studied by Murachi (1962). Effects of D.D.T., B.H.C., and Lindane in tissues of *Ophiocephalus punctatus* and *Heteropneustes fossil* have been studied by Mathur (1962a, b). Hypertrophy of hepatic cells, necrosis and margination of cells in the liver of *O. punctatus*, and atrophy of a few cells, margination and hypertrophy of parenchymatous cells, including necrosis in the liver of *H. fossilis* were observed by the action of D.D.T. Lesions were formed in the liver even at the low dosages of 10 ppm B.H.C. and 5 ppm Lindane. Other changes produced by these latter compounds were margination, vacuolation of hepatic cells, atrophy, etc.

4 GENERAL REMARKS

It is apparent from the above account that knowledge so far gained on the subject from the Asia-Far East region is generally on the different parasites infecting fishes, with scattered observations on the host-parasite relationships, pathological effects and control methods. This can be partly attributed to the fact that the majority of the investigations have been taken up at University level and to shortage of facilities and trained staff for conducting fish pathological studies. Some basic information is now available on the important parasites and some of the common epidemic diseases affecting cultured fishes of the region. The main fields in which emphasis may be laid in the future are, control of infections occurring in hatcheries or nurseries, pathology and therapy of bacterial and virus diseases, nutritional deficiencies and development of disease-resistant strains of fish. It is also necessary that co-ordinated attempts should be made to evolve standardized control methods against some of the common infections by fungus, *Trichodina*, *Argulus*, *Lernaea*, *Gyrodactylus*, etc., so that pisciculturists may be able to take necessary action at short notice.

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CONTROL OF CARP DISEASES IN THE U.S.S.R.

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Abstract

In recent years the diseases of carp in the fish farms of the U.S.S.R. were intensively studied and based on the exact knowledge of causal agents, scientific methods for control against epidemics have been developed.

The treatment of diseases prescribed are in the form of baths, injections or oral medicaments mixed with food. The most successful means of controlling disease is by application of small doses of curative agents directly into ponds.

New diseases have been recorded in fish farms of the U.S.S.R. in recent years. A number of pathogenic parasites came from the Far East with the young fish imported into fish farms in the European part of the U.S.S.R. The danger has decreased considerably as a result of the introduction of quarantine measures.

LUTTE CONTRE LES MALADIES DE LA CARPE EN U.R.S.S.

Résumé

Au cours des dernières années, les maladies des carpes dans les exploitations piscicoles de l'U.R.S.S. ont fait l'objet d'études intensives et, sur la base de la connaissance exacte des agents étiologiques, des méthodes scientifiques de lutte contre les épizooties ont été mises au point.

Divers traitements sont prescrits sous forme de bains, d'injections ou de médicaments mélangés aux aliments. On a constaté que la méthode la plus efficace consistait à déverser directement dans les étangs les substances curatives à faible dose.

De nouvelles maladies sont apparues dans les exploitations piscicoles de l'U.R.S.S. au cours des dernières années. Un certain nombre de parasites pathogènes en provenance de l'Extrême-Orient ont été introduits avec de jeunes poissons importés dans les établissements piscicoles de la Russie d'Europe. Le danger a pu être en grande partie éliminé grâce à l'application de mesures de quarantaine.

LUCHA CONTRA LAS ENFERMEDADES DE LA CARPA EN LA U.R.S.S.

Extracto

En estos últimos años se han estudiado intensamente las enfermedades de la carpa en las piscifactorías de la U.R.S.S., y tal estudio se ha basado en el exacto conocimiento de los agentes causales. Se han ideado métodos científicos para la lucha contra las epidemias.

Los tratamientos prescritos para las enfermedades consisten en baños, inyecciones, o medicamentos por vía oral mezclados con la alimentación. Los medios más eficaces de controlar las enfermedades consisten en la aplicación de pequeñas dosis de sustancias curativas directamente en los propios estanques.

En las piscifactorías de la U.R.S.S. se han registrado en estos últimos años nuevas enfermedades. Varios parásitos patógenos provinieron del Lejano Oriente con las crías de peces importadas en las piscifactorías de la parte europea de la U.R.S.S. Este peligro ha disminuido considerablemente como consecuencia de la implantación de medidas de cuarentena.

1 INTRODUCTION

Carp culture has increased considerably since a paper summarizing control of carp (*Cyprinus carpio*) diseases of the U.S.S.R., was prepared ten years ago (Bauer, 1958a). Carp are now cultured in large quantities, not only in the European part of the U.S.S.R., but also in Siberia, Kazakhstan and Middle Asia republics. The quantity of cultured carp has increased in the north west districts, in Baltic republics, Byelorussia and so on. This is the result of both construction of new fish farms and of some intensification of methods which enable the culture of more fish per unit area.

During these years experience on the control of fish diseases has naturally been gathered which helps to diminish the losses. Many new methods proposed by Soviet and foreign scientists are now being used. But during the same period, some new carp diseases, of infectious and parasitic nature, never before observed in Soviet fish farms have been recorded.

The number of specialists on carp diseases has increased. The basic investigations are undertaken at the State Research Institute of Lake and River Fisheries (Gos NiORCH, former WNiORCH), at the All-Union Research Institute on Pond Fish Culture (WNiPRCH), at the Ukraine Research Institute of Fisheries (UcrNiiRCH), at the All-Union Institute of Experimental Veterinary (WiEV) and some others.

When developing disease control methods, the Soviet specialists pay particular attention to the biology of the pathogenes of the mass diseases, their epizootology and pathogenesis, and to the methods of prophylaxis and treatment, and also to the physiological condition of fish. The organism in full health is more resistent than a weak one (Dogiel and Bauer, 1955). This statement is now confirmed by biochemical and immunobiological data.

2 CARP DROPSY

This is the most dangerous infectious disease of carp in some districts, causing mass mortalities. Contrary to Schäperclaus (1954), who asserted the bacterial nature of dropsy, the Soviet scientist already in the thirties spoke of the virus nature of the disease. Much has been done by Peshkov (1951) and Goncharov (1954; 1959), but they could not give direct proofs of this hypothesis. Investigations of GosNiORCH using fish cultures (Tez, 1961; 1963; Tez and Jacovleva, 1962) were not finished because of the death of their pioneer, but the experiments of Tomasec *et al.*, (1964) showed that they were along the right lines, and the virus nature of dropsy must be stated now as scientifically proved. Histological investigations of Factorovich proved the existence of intracellular virus corpuscles in the brain, but only in the isthmus ganglion, and only in fishes having the acute form of the disease.

By the end of the fifties we had begun to use for treatment, but chiefly for prophylaxis, medicine proposed by Schäperclaus (1955; 1956) and Volf and Havelka (1961) - antibiotics, chiefly levomycetin, and the antiseptics, such as methylene blue (Kanaiev, 1959; Nechiporenko *et al.*, 1962). The use of these, as well as the limitation of fish transportation, sanitation of ponds, hybridization of the carp and the Amursazan (*Cyprinus carpio haematopterus*) were followed by decreases in losses caused by dropsy in some districts of the U.S.S.R. At the end of the fifties the losses were about 50 percent of carp yearlings in the Ukraine fish farms; now the losses are insignificant.

The results of dropsy control are not so obvious in the fish farms of North Caucasus and Middle Asia, for the wild carp inhabits the water bodies, the water sources of the farms and this carp is the natural reservoir of the disease. The best way to control dropsy in these districts is to breed resistant carp strains. Kirpichnikov had begun to work in this way and has shown that carp of different genetic origins have different resistances. Studies of this kind are promising for fisheries development and need to be increased.

3 AIR BLADDER DISEASE

During recent years a new carp disease has been observed in some carp rearing districts. The chief symptom of it is the inflammation and then the destruction of one of the parts of the air bladder. Sometimes the disease is followed by mass losses, which can be up to 100 percent among the fingerlings. A hypothesis had been formulated that the disease was caused by bad quality feeds (Metelev, 1963; 1964). Nechiporenko (1963; 1965) thinks it is a derivative of dropsy. The careful study done in GosNiORCH had showed that the disease is a contagious and acute one of independent origin. It is now proved that the transportation of young fish and spawners from farm to farm has spread the disease during the last few years. The hybrids Cyprinus carpio x C. carpio haematopterus are more resistant than the pure carp. The disease is not spread by the fish eggs. The Soviet method of rearing carp eggs and fry in which there is no contact between the eggs and the spawners, can be used for the sanitation of fish farms and to prevent the spread of the disease to new places. Though it needs further investigation, this disease may be called danger No. 2 for carp culture. Of less importance in the U.S.S.R. are such infectious diseases as branchiomycosis, mucophyllosis and some others.

4 PARASITIC DISEASES

Among the parasitic diseases the most dangerous is ichthyophthiriosis. In the beginning of the fifties it was the cause of severe epizootics in the north-west districts of the U.S.S.R., in the Baltic republics and Byelorussia, and at the end of the fifties it caused heavy losses in the Ukraine, Middle Asia and Kazakhstan. All species of fresh-water fishes undergo the infection especially at the high population densities used in artificial conditions. To determine control methods, the biology of the pathogene Ichthyophthirius multifiliis has been studied (Shchupakov, 1951; 1954; Bauer, 1953; 1955; 1958b; 1959). The most interesting part of this investigation is the discovery of the superinvasion immunity of fishes under the Ichthyophthirius infection. Though the nature of this phenomenon is not quite clear, it explains the peculiarities of the epizootic process, in particular the outbreak of the disease in a fish farm just after the arrival of the parasite with the transferred fishes. The problems of fish immunity, which appears under the influence of Ichthyophthirius as well as of other parasites, must be thoroughly studied using the methods of contemporary immunobiology.

Recently the pathogenesis of the disease has been studied and biochemical and haematological indices have been used (Reshetnikova, 1962; Avdosiev, 1964).

On the basis of biological investigations control methods have been developed. These include quarantine of the infected fish farms, removal of the spawners from the spawning ponds just after spawning has occurred, the destruction of wild fish populations and so on. But till the last few years there were no effective remedies to cure the infected fish. Baths of 0.6 to 0.7 percent NaCl, (Bauer and Demchenko, 1960) are effective, but are not profitable when we have to save large quantities of fish. Deufel (1960), proposed malachite green for Ichthyophthirius control. This treatment is widely used in the U.S.S.R. It is used both in baths and in natural conditions when the reagent is introduced directly into ponds. For big ponds Avdosiev (1962) proposed to make a plastic barrier round the feeding areas and put the malachite green into such a "yard". Unfortunately this agent has been found to be carcinogenic. Another treatment used in the U.S.S.R. is the application of dilute solution of formalin, but its effectiveness in controlling Ichthyophthirius is not yet established.

5. CHILODONELLOSIS

This is rather a dangerous disease of carp yearlings, especially in the north-west districts during the long winter. Now the losses are minimal due to using the more winter-stable hybrids of the carp and amursazan (carp from Amur) the rearing of well-fed, winter-prepared, physiologically valuable carp fingerlings and by the sanitation of winter ponds and fishes. The latter is achieved by bathing the fishes in medicinal solutions – NaCL, NH_4OH etc. During recent years to control *Chilodonella cyprini* agents such as NaCL, malachite green and gaseous chlorine have been applied in the winter ponds. The solution of even 0.1-0.2 percent NaCL destroys the parasite and cures the fishes.

6 CARP COCCIDIOSIS

This sometimes causes mass losses of fingerlings and one-summer fishes. More dangerous is coccidiosal enteritis, caused by *Eimeria carpelli* (*E. cyprini*, *E. cyprinorum*, *E. wierzejskii*). The investigations of the last few years (Zaika and Kheisin, 1959; Zmerzlaia, 1964) have shown that the oacysts are very sensitive to drying. Wild fishes living in the ponds are the reservoir of the disease. Biological methods of coccidia control have been worked out, but treatments are not so advanced. Data on curing enteritis with osarsol (Naumova and Kanaiev, 1962) are not very trustworthy. The pathogen of the knot coccidiosis, *E. subepitelialis*, has been found in the fish farms of Latvia and Ukraine, but is not yet dangerous.

7 CARP DACTYLOGYROSIS

Carp dactylogyrosis caused by *Dactylogyrus vastator* and *D. extensus* has been thoroughly investigated in the U.S.S.R. (Layman, 1948; 1951; Bauer, 1951; 1954; 1959; Bauer and Nikolskaya, 1954; Bykhovski, 1957; Izumova, 1956a; 1956b; 1958; Sadkovskaya, 1958; Uspenskaya, 1961). The biology of the pathogenic agents, epizootology and pathogenesis have been studied carefully. In addition to biological measures some chemical means for controlling these diseases have been evolved, of which ammonia baths proved to be the most effective (Pasovsky, 1953; Lavrovsky and Uspenskaya, 1959). Application of the measures on a large scale will enable us in the near future to eradicate dactylogyrosis caused by *D. extensus* in ponds. Sarig, Lahav and Shilo (1965) have recently found it possible to control carp dactylogyrosis by introducing the insecticide dipterex directly into ponds and this has created great interest in the U.S.S.R.

8 CARP DISEASES CAUSED BY TREMATODES

8.1 Sanguinicolosis

Sanguinicolosis is caused by a parasite of the circulatory system, *Sanguinicola inermis*. It is dangerous for the carp alevins and fingerlings mainly in the southern regions in ponds densely populated with molluscs of Lymnaeidae family.

The biology of this disease was thoroughly studied recently by Chechina (1959) and by Naumova (1961a; 1961b; 1961c). They prescribe a complex of biological measures resulting in a complete eradication of the disease. Most important of these measures are drying and sanitation of ponds which lead to a complete eradication of molluscs.

8.2 Black spot disease

The pathogene of black spot disease, the trematode *Posthodiplostomum cuticola*, has not been studied carefully. The disease causes mass mortality of young carp in ponds and natural waters. Even the first intermediate host was not known until Vladimirov (1960; 1961a; 1961b; 1961c) found it to be the mollusc *Planorbis planorbis*. The morphology and ecology of the early stages of development of *P. cuticola* were then studied as well. The eggs develop only at temperatures above 10°C, which is why the disease is characteristic of the southern regions of the country. The temperature optimum for *P. cuticola* development is 24 to 28°C.

It is possible to control this disease by the eradication of the mollusc *Planorbis planorbis* and piscivorous birds of the genus *Ardea* and closely related genera.

9 DISEASES CAUSED BY CESTODES

Some cestodes are also very pathogenic for the carp. Representatives of the family Caryophyllaidae are the most important. Formerly it was believed that the agent of the carp caryophyllosis is *C. fimbriceps* which was often mistaken for *C. laticeps*. However, it was found not so long ago (Kulakovskaya, 1961; Kulakovskaya and Krotas, 1961), that *Khawia sinensis* is more dangerous. This helminth was introduced into the European part of the U.S.S.R. from the Far East together with the Amur wild carp and is now widespread throughout the fish farms, where it is gradually substituting *C. fimbriceps* as the primary agent of caryophyllosis. At present carp caryophyllosis is controlled both by means of biological and medical treatments, such as Kamala, phenothyasine and phelixan added in definite proportions to artificial feeds given to the carp.

The agent of bothriocephalosis, *Bothriocephalus gowkongensis*, is also of Far-Eastern origin. It is distributed in the Amur river and water bodies of China, where it is found primarily in the grass carp (*Ctenopharyngodon idella*). The parasite came in with the young grass carp to the fish farms of the U.S.S.R. It passed easily to the carp and other Cyprinidae and caused severe losses of young carp. Year by year *B. gowkongensis* spreads to new regions due to the mistakes of fish culturists. For bothriocephalosis control the ponds and fish should be disinfected. Helminths are to be controlled by the same means as used in caryophyllosis (Musselius, 1962; 1963).

One more pathogenic parasite has come to the pond farms of the western zone of the U.S.S.R. from the Far East. This is the agent of carp philometrosis, caused by the nematode *Philometra lusii* (Vismanis, 1962; 1964; Vasilkov, 1964; Kusmovich, 1964), a species new to science. Large females of the species encyst under the carp scales and cause hard lumps. Vismanis managed to find very small females and males of the parasite in the walls of the swim bladder. Various cyclops turned out to be the first intermediate hosts of *P. lusii*. The main control measure against the disease is to avoid rearing carp of different ages in the same pond. Careful application of the above measures will provide for a complete sanitation of a pond farm.

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PARASITES AND DISEASES OF THE GRASS AND SILVER CARPS IN FISH FARMS OF THE U.S.S.R.

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Abstract

Nineteen species of parasites were found to occur in grass and silver carps (*Ctenopharyngodon idella* and *Hypophthalmichthys molitrix*), five of which caused diseases (Table III). Parasites of these fishes may be divided into two groups: one group introduced into the country along with these fishes and the other that was transmitted to them from other cultivated fishes in the farms (Table III). Prophylactic and control measures against most of the known diseases have been developed.

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PARASITES ET MALADIES DE LA "GRASS CARP" ET DE LA "SILVER CARP" DANS LES ELEVAGES PISCICOLES D'U.R.S.S.

Résumé

Dix-neuf espèces de parasites ont été dénombrées chez la "grass carp" et la "silver carp" (Ctenopharyngodon idella et Hypophthalmichthys molitrix), dont cinq étaient à l'origine de certaines maladies (Tableau III). Les parasites de ces poissons peuvent être classés en deux groupes : l'un introduit dans le pays avec les poissons et l'autre comportant les parasites qui leur ont été transmis par les autres poissons élevés dans les exploitations (Tableau III). Des mesures prophylactiques et de lutte contre la plupart des maladies connues ont été mises au point.

PARASITOS Y ENFERMEDADES DE LAS CARPAS HERBIVORA Y PLATEADA EN LAS PISCIFACTORIAS DE LA U.R.S.S.

Extracto

En las carpas herbívora y plateada (Ctenopharyngodon idella y Hypophthalmichthys molitrix) se observó la presencia de diecinueve especies de parásitos, cinco de los cuales determinaron enfermedades (Cuadro III). Los parásitos de estos peces pueden clasificarse en dos grupos: un grupo introducido en el país junto con dichos peces, y otro, transmitido a éstos por otros peces cultivados en granjas piscícolas (Cuadro III). Se han ideado medidas profilácticas y de lucha contra la mayoría de las enfermedades conocidas.

1 INTRODUCTION

In recent years the culture of phytophagous fishes has attracted the attention of fish breeders and scientists. The silver carp (Hypophthalmichthys molitrix) and grass carp (Ctenopharyngodon idella) have proved to be the most suitable for rearing in ponds. The former feeds on phytoplankton and the latter on higher aquatic plants. Aristichthys nobilis feeding on zooplankton and Mylopharyngodon piceus feeding on molluscs were transported to the U.S.S.R. besides the phytophagous fishes, though in small numbers. The first spawners for rearing in pond farms were transported from the Amur River in small quantities and then large numbers of fry were transported from Mainland China. We now have in the U.S.S.R. our own spawner stock reared from imported fry. The progeny of these spawners are stocked successfully in inland water bodies and pond farms of the U.S.S.R.

When rearing any fish we inevitably meet various fish diseases, therefore it is very important to study the parasite fauna and diseases of these fishes, and to develop measures for their control in the pond-fish farms of the U.S.S.R.

2 PARASITES IMPORTED WITH PHYTOPHAGOUS FISHES

We shall discuss briefly the parasite fauna and diseases of phytophagous fishes in China for fry of the species were transported to our farms from there. Phytophagous fishes have a rather rich parasite fauna according to published data (Handbook on Parasites of Fresh-Water Fishes of the U.S.S.R.). For instance, the grass carp has approximately 30, and the silver carp about 40 species of parasites. The majority of these parasites in the adult grass and silver carps are mainly ones with a direct cycle of development, or parasites actively penetrating the fish body. Most of them are Protozoa or Monogenoidea. This peculiarity of the parasite fauna of phytophagous fishes is connected with the character of their nourishment. The incidence of large numbers of infusorians (many of which inhabit the intestine) is common in the intestinal fauna of animals feeding on vegetable food (Strelkov and Shulman, 1964).

Chinese parasitologists describe a number of infectious diseases of phytophagous fishes. However, all of these were found in pond-fish farms only. No infectious diseases were found in the natural water bodies from which these fishes were transported to the U.S.S.R.

The species composition of parasites of fry imported from China does not vary significantly with the years, and it includes seven species (Table I). The fry are caught in natural water bodies at the age of 25-40 days. The silver carp usually carries one species of sporozoa on the gills, Trichodina on the skin, two species of Dactylogyrus on gills and Diplostomulum spathaceum in the lens of the eye.

The young grass carp are usually infected by Dactylogyrus lamellatus, and less frequently by D. ctenopharyngodonis. Metagonimus yokogawai were recorded twice. As can be seen from Table I, all parasites of imported fry are either parasites with direct cycles of development or they actively penetrate the fish body. No parasites causing fish mortality were found when investigating fish transported from China, or they were found in insignificant numbers only (Musselius and Strelkov, 1966). In spite of this all imported fishes were quarantined for a year to take measures in case some disease arose. When in quarantine some parasites were recorded which were not found while examining the imported fish, due to the extreme scarcity of their occurrence. During the quarantine period nine species of parasites were recorded (Table II) (Bauer and Strelkov, 1963). Two of them, Trichodina and Gyrodactylus ctenopharyngodonis caused the mortality of grass carp fry in one of the southern pond-fish farms in 1960. Dactylogyrus and Diplostomulum were found in grass carp as well. Sometimes Bothriocephalus gowkongensis was found in grass carp in autumn; it disappears usually in spring. The infection by Dactylogyrus lamellatus is as a rule more intense in spring when the number of parasites is rather high (up to 170 parasites on a small-sized fry-of-the-year of about 1.5 g weight).

Table I

The parasites infecting grass and silver carp fry imported from China

Parasite species	Grass carp	Silver carp
Myxosporidia sp.	—	+
Trichodina sp.	—	+
Dactylogyrus hypophthalmichthys	—	+
D. ctenopharyngodonis	+	—
D. lamellatus	+	—
Metagonimus yokogawai	+	+
Diplostomulum spathaceum	—	+

Table II

Parasite infections of grass carp and silver carp
revealed during the quarantine period

Parasite species	Grass carp	Silver carp
Trichodina sp.	+	+
Ichthyophthirius multifiliis	+	+
Chilodonella cyprini	+	—
Dactylogyrus ctenopharyngodonis	+	—
D. lamellatus	+	—
D. hypophthalmichthys	—	+
Gyrodactylus otenopharyngodonis	+	—
Bothriocephalus gowkongensis	+	—
Diplostomulum spathaceum	+	+

Three species of parasites were usually found on silver carp. In spite of the small number of samples gathered during the quarantine period some parasites were recorded which were not found by ichyopathologists when examining fish immediately after they had been transported from China. Of prime importance among these was Bothriocephalus gowkongensis, a parasite dangerous for the young grass carp and also for many of our Cyprinidae, particularly common carp and wild carp. Furthermore, keeping fish in quarantine was also of use as a large number of trash fish transported from China together with fry of the plant-eating fish could be eliminated during that period (Bauer and Strelkov, 1963).

Further observations on the parasite fauna of the phytophagous fishes have shown the increase of a number of parasitic species. The total number of parasites revealed was 19 (Table III). The increase in number of parasite species may be explained by two causes. First, parasites were recorded which were not noticed when first examining the fish and which were revealed only by keeping fish in ponds at high stocking rates. Such parasites are: Eimeria sinensis, Dactylogyrus skrjabini, D. nobilis, Sinergasilus major and S. lieni. Secondly, some parasites common to our pond fishes were found on the introduced fish as well. They are Khawia sinensis and Lernaea cyprinacea which infected them during their combined rearing with carp and goldfish.

3 DISEASES OF PHYTOPHAGOUS FISHES

The majority of parasites of the phytophagous fishes are characteristic only of them and do not infect our common pond fishes, excluding Bothriocephalus gowkongensis which proved to be pathogenic to our carp and wild carp both in pond-fish farms and natural water bodies. This parasite is distributed in many pond farms and natural water bodies, and heavy invasions may cause carp and wild carp mortality. Of 19 parasite species found in pond-fish farms of the U.S.S.R., five caused fish diseases and mortality (Bauer, Babaev and Strelkov, 1963; Musselius, 1965).

3.1 Bothriocephalosis

The pathogenic agent B. gowkongensis was transported from China with fry of the grass carp. The environmental conditions of pond farms, especially of southern ones, proved to be favourable for the development of the parasite and it is now distributed among many of our Cyprinidae. There are data on infection by this parasite of common carp, wild carp, goldfish (Carassius auratus, C. carassius) and other Cyprinidae. The stages of the developmental cycle in pond-fish farms of the U.S.S.R. are approximately the same as in China. Intermediate hosts are our common cyclops, wide-spread in plankton. Bothriocephalosis is controlled by eradicating the parasite eggs from pond bottom by means of chloride of lime and by treating the fish with kamala which is either given with food or introduced directly into the intestine with the help of a syringe and a rubber catheter attached to it instead of a needle (Musselius, 1960; 1963a,b).

3.2 Synergasilosis

Crustacea of the genus Synergasilus are pathogenic agents of this disease. S. major parasitizes grass carp gills and S. lieni silver carp gills. Measures for controlling this parasite are not yet completely developed. Chinese ichthyopathologists suggest a mixture of copperas and green copperas to cure synergasilosis (Hsu Me-veng, Jen Yung-feng, 1955). However this method does not provide for the complete recovery of the fish. Rearing the fish of different ages separately is an important prophylactic measure, for it is known that S. major does not infect fish younger than two years (Bauer and Babaev, 1963).

3.3 Coccidiosis

This disease caused by Eimeria carpelli was found in the silver carp at some southern fish farms of the U.S.S.R. Control measures have not yet been developed. Special attention is paid to prophylactic measures and disinfection of ponds.

Table III

The infection of Far-East fishes reared in pond-fish farms of the U.S.S.R.

Parasite species	*Ctenopharngodon idella*	*Hypophthalmichthys molitrix*	*Aristichthys nobilis*
Cryptobia branchialis	−	+	+
Eimeria sinensis *	−	▨ +	▨ +
Trichodina sp.	+	+	+
Ichthyophthirius multifiliis *	+	+	−
Dactylogyrus ctenopharyngodonis	▨ +	−	−
D. lamellatus	▨ +	−	−
D. skrjabini	−	▨ +	−
D. hypophthalmichthys	−	▨ +	−
D. nobilis	−	−	▨ +
Gyrodactylus ctenopharyngodonis *	▨	−	−
Bothriocephalus gowkongensis *	▨	−	−
Khawia sinensis	▩	−	−
Diplostomulum spathaceum	+	+	+
Posthodiplostomum cuticola	▩ +	▩ +	▩ +
Tetracotyle sp.	▩ +	−	−
Lernaea cyprinacea	−	▩ +	−
L. ctenopharyngodonis	▨	−	−
Sinergasilus major *	▨	−	−
S. lieni	−	▨ +	▨ +

*	Species caused mortality
▨	Species imported from China
▩	Species transferred to the Far-East fishes from our common pond fishes

3.4 Posthodiplostomatosis

The pathogenic agent, metacercaria of *Posthodiplostomum cuticola* occurs in the phytophagous fishes of the southern fish farms of the U.S.S.R. in large numbers. The silver carp is most affected by posthodiplostomatosis. Control measures consist of eradication of molluscs and sea gulls.

3.5 Tetracotylosis

Recently this disease, caused by parasitization with digenetic trematodes larvae of the genus *Tetracotyle*, has been recorded rather frequently in the grass carp. The disease is characterized by the scales of the fish bristling, a reddish abdomen and hydropsy.

An analogous disease was observed by Radulesku and Georgesku (1963) in the grass carp transported to Rumania.

3.6 Lernaeosis

This disease is caused by *Lernaea cyprinacea* parasitizing mainly goldfish. It was found on young grass carp reared together with goldfish in one of the fish farms in the south of the U.S.S.R. Baths of weak $KMnO_4$ solution are applied to eradicate the parasite (Musselius and Strelkov, 1966).

Experience of controlling the diseases of phytophagous fishes in the U.S.S.R. has shown that they can be cured with the same means as in the case of carp diseases. When treating phytophagous fishes in medicative baths, one must take into consideration that they can be injured easily and that is why not more than 1,000 fingerlings are to be put per 100 litres of solution (Musselius and Strelkov, 1966).

Of infectious diseases, dropsy was recorded in these fishes in one of the fish farms of the U.S.S.R. The disease was accompanied by fish mortality. Probably the grass carp infected carps reared together with them. At present no cases of this disease have been recorded in the grass carp. Evidently they are more resistant to dropsy than carps; but they may serve as a source of infection (Konradt and Faktorovich, 1963).

Research on the parasite fauna and diseases of the phytophagous fishes will continue. It is necessary to decide which diseases of our pond fishes may be dangerous to them when they are reared together, and which parasites may cause diseases and mortality of fish. Measures for prophylaxis and control of diseases will also be developed. Special attention is to be paid to the biology and life cycle of parasites of these fishes under conditions of pond farms and in natural water bodies.

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ERADICATION OF ICHTHYOPHTHIRIUS MULTIFILIIS IN CARP

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Abstract

Quicklime was applied in carp ponds to control the Ichthyophthirius multifiliis infection. A dose of 3,000 kg of lime per ha administered in two lots proved safe for fish and destructive to the parasite.

ERADICATION D'ICHTHYOPHTHIRIUS MULTIFILIIS CHEZ LA CARPE

Résumé

Des épandages de chaux vive ont été pratiqués dans des étangs de carpiculture pour lutter contre des infections d'Ichthyophthirius multifiliis. Les expériences ont prouvé qu'une dose de 3.000 kg de chaux par hectare, déversée en deux lots, ne présentait aucun danger pour le poisson tout en détruisant les parasites.

ERRADICACION DE ICHTHYOPHTHIRIUS MULTIFILIIS EN LA CARPA

Extracto

Para luchar contra la infección de Ichthyophthirius multifiliis se utilizó la cal viva en los estanques de carpa. Una dosis de 3.000 Kg de cal por ha, administrada en dos porciones, resultó inocua para los peces y destructora para los parásitos.

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1 INTRODUCTION

The object of the present report is to outline a method of combatting parasitic infection of the fry of carp (Cyprinus carpio). The measures suggested here are simple and inexpensive.

An increased incidence of parasitic diseases, including that caused by Ichthyophthirius multifiliis, has been observed in recent years. This parasite attacks carp when densely concentrated, for example, young fish in fry ponds in spring, and commercial carp in holding pools in autumn and winter, and is very difficult to eradicate.

2 COMMON METHODS OF ERADICATING ICHTHYOPHTHIRIUS MULTIFILIIS

When a small number of parasites have been discovered, the following measures have been recommended (Bauer, 1955; 1956; Kocylowski, 1962; Schäperclaus, 1954):

(i) Prompt removal of fish from fry ponds and transfer to fingerling ponds. This procedure gives good results in small fry ponds from which the young fish population can be quickly caught.

(ii) In the case of an intense parasitic invasion, it is advisable to hold fish in fast-flowing water for a period of time corresponding to that required by the youngest forms of the parasite to reach the adult stage, as thereafter the parasite leaves its host. This measure fails, however, to produce entirely satisfactory results because the strong discharge of water keeps fish under constant stress, which combined with enforced starvation at warm-water temperatures, causes exhaustion of the fish.

(iii) A bath in 0.5 percent common salt solution in pools or small ponds is effective, but owing to the high cost of salt, it can be applied only in small ponds, for instance in holding pools in exceptional cases to save valuable fish, such as spawners.

3 USE OF QUICKLIME

The above means of combatting the parasite cannot be considered satisfactory because they are either difficult to carry out without detriment to the fish, or involve an unduly high cost.

In the course of investigations on methods of extermination of Ichthyophthirius multifiliis thriving on the epithelium, various substances have been tested, among which quicklime was singled out as a cheap remedy suitable for extensive application in ponds (Rychlicki and Hlond, 1963).

Very strong doses of lime were tried for the treatment of fish. In this method, lime is distributed over the entire water surface, thus making a curative bath without the need to capture fish for treatment.

This measure, before being applied in ponds, was tested in the laboratory. The parasites were found to die within three hours after the pH value of water had been raised by means of lime from the normal for ponds (7 to 7.5) to 8.5 to 9. By raising the pH value of water for a period of time corresponding to that required by the youngest stages of Ichthyophthirius multifiliis to develop, it was possible to clear the fish of this parasite.

The treatment used was 3,000 kg of quicklime per ha of fry pond area (in this country fry ponds are those in which carp are reared from the age of a few days to about a month). The above dose administered in two lots at two-day intervals would increase the pH value of water from 7-7.5 to 8.5 for a sufficiently long period of time.

4 EXAMPLES OF THE USE OF LIME IN PONDS

The procedure followed and results obtained when treating three carp ponds to combat Ichthyophthirius multifiliis invasions were as follows:

(a) Fry pond "Bugaj", 0.8 ha in area

1 June 1963	Hatched carp, numbering 80,000 individuals, were introduced from the spawning ground.
17 June	Microscopic examination showed one to six parasites on the skin and two to ten individuals on the gills of the fish.
21 June	1,850 kg/ha lime was distributed; pH of water - 8.5.
22 June	Parasites still present on fish.
25 June	1,250 kg/ha lime was distributed.
2 July	No parasites; pH of water - 8.5.
4 and 11 July	No parasites.
18 July	30,000 fry of 2-4 g weight were caught; survival was 37.5 percent.

(b) Fry pond "Spytkowice", 1 ha in area

25 May 1963	Hatched fry, numbering 80,000, introduced from spawning grounds.
18 June	Microscopic examination revealed one to four parasites on skin, and one to seven on the gills.
21 June	1,500 kg/ha lime was distributed.
22 June	Continued presence of parasites on fish.
25 June	1,000 kg/ha lime distributed.
8 July	No parasites on fish; pH of water - 8.5.
10 July	36,700 fry of 2-4 g weight were caught; survival was 45.9 percent.

These were subsequently released into a fingerling pond, from which fish weighing on an average 125 g were caught in spring 1962; survival was 94.2 percent.

(c) Fingerling ponds "Wierzbowiec Nowy", 9 ha in area

6 July 1963	162,000 fry, individual weight 2-4 g, were released in the pond.
3 August	No parasites.
28 August	I. multifiliis present: one to four in the field of vision on the skin, and 4 to 32 on the gills; pH of water 6.5 to 7.
29 August	1,250 kg/ha lime distributed.
30 August	pH of water - 9.

31 August	Parasites found on gills only; one to five individuals in the field of vision; pH of water 8.5 to 9.
2 September	Fewer parasites; pH of water 7 to 7.5.
3 September	1,350 kg/ha lime distributed; pH of water - 10.
4-9 September	No parasites; pH - 10 going down to 9.5.
4 May 1964	105,800 individuals caught, weight 35 g; survival 66 percent.

No injuries to the fish or any adverse effects due to the action of lime were found. It follows that a strong lime bath in the pond is not dangerous to carp in its first month of life. The young fish under examination exhibited an unusual endurance, while tadpoles were found to die on a mass scale. During the treatment, young fish behaved in a normal way and no symptoms of suffocation were observed.

The above results are encouraging and show that high doses of lime can be used for eradicating *Ichthyophthirius multifiliis* from ponds, provided the pH is maintained within safe limits.

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EXPERIMENTS IN VITRO CULTURE OF ICHTHYOPHTHIRIUS MULTIFILIIS

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Abstract

Several media for culturing *Ichthyophthirius multifiliis* were tried. Dried, powdered and pasteurized fish slime appeared to be most suitable. Slime powder in the proportion 0.3 g per 100 ml water was used successfully for *Ichthyophthirius* culture.

EXPERIENCES DE CULTURE IN VITRO D'ICHTHYOPHTHIRIUS MULTIFILIIS

Résumé

Divers milieux ont été expérimentés pour la culture d'*Ichthyophthirius multifiliis*. Les meilleurs résultats ont été obtenus avec du mucus de poisson séché, réduit en poudre et pasteurisé. Une solution de 0,3 g de mucus en poudre par 100 ml d'eau a été utilisée avec succès pour la culture d'*Ichthyophthirius*.

EXPERIMENTOS DE CULTIVO IN VITRO DE ICHTHYOPHTHIRIUS MULTIFILIIS

Extracto

Se ensayaron diversos medios para el cultivo de *Ichthyophthirius multifiliis*. El más apropiado resultó el mucus seco, pulverizado y pasteurizado, de pescado. El mucus en polvo en la proporción de 0,3 gramos por 100 ml de agua se utilizó con éxito para los cultivos de *Ichthyophthirius*.

IX/E-4

1 INTRODUCTION

One of the most frequent parasites encountered among pond fishes (carp, trout, etc.) is Ichthyophthirius multifiliis Fouquet, which produces a dangerous disease of the epithelium. Since all age groups of carp, including fry, are susceptible to the disease, it presents a serious problem for pond fishery management. This has made it necessary to counteract the parasitic invasions with the aid of effective measures, both preventative and curative.

Reports from many countries indicate that the disease is common over a wide area. Various methods of destroying its centres are recommended, as for example, biological and chemical measures consisting in the elimination of parasites by means of various curative baths (e.g. Almacher, 1961; Bauer, 1955; Kocylowski and Miączynski, 1960), as well as by the administration of chemicals to the water of the endangered pond (Rychlicki and Hlond, 1963). A verification of the effectiveness of these measures would be facilitated if it were possible to use them on pure in vitro cultures of the parasite.

This paper gives the results of experiments carried out with a view to determining whether it is possible to breed young individuals of this parasite under laboratory conditions.

2 PROPAGATION ON A MEDIUM CONTAINING SLIME

The medium used for the propagation of young individuals in the first stage of the experiments was based exclusively on fresh slime. Before use it was repeatedly tested for the presence of the parasite at any stage of its development.

The culture of the tomit stage of the parasite was based on a medium made up of two constituents only, namely slime and water. First of all, a slime suspension was prepared in the proportion of 5 g fresh slime per 100 ml filtered tap water. After thorough mixing, the medium was poured into petri dishes which had been carefully washed and sterilized before use. The layer of the medium in the dishes was 0.5 cm thick.

Fifty replications were made for the purpose of observing the development and rate of growth of parasites on slime. About a hundred young parasites were placed in each medium by means of a Pasteur pipette. The temperature of the medium was 17 to 18°C. The cultures were kept under cover at room temperature.

The experiments in the propagation of the parasite on a medium containing slime gave a positive result. A gradual increase in the number of parasites was observed in individual dishes in almost all cases although the rate of development of the cultures was not always identical. A decay of the slime substance, if not too extensive, did not hold back their development. Generally good vitality of the stocks was observed throughout the experiment.

However, the medium employed is unstable and in view of this, an attempt was made to use suitably processed slime instead of fresh slime.

3 POWDERED SLIME MEDIUM

Fresh slime was dried and ground under conditions of full sterility. Thus prepared it could be readily kept at room temperature for a period of eighteen months without any fear of its losing the nutritive qualities.

For practical use, powdered slime is superior to fresh slime. The media made of dry slime while exhibiting the same qualities as those previously used, featured an insignificant microbial contamination.

The method of preparing the medium was devised as follows: the base was provided by about 250 ml of fresh slime gathered from 120 live carp individuals weighing on an average 800 g. It was collected from the entire body surface of the fish.

In order to remove excess water, the slime was squeezed through a dense gauze and then mixed in a mortar. Next it was spread in thin layers on slides and placed in a drier at 60°C for three to four days. The product obtained was finely ground in a mortar and sieved. The end-product was then pasteurized in a sterilizer (80 to 85°C).

The actual medium was made in the proportion 0.3 g of pasteurized slime powder to 100 ml of filtered tap water.

4 OTHER MEDIA

Apart from slime, other carp body constituents were tested, after suitable processing for use as media for the propagation of parasites. These were: gills, skin, muscular tissue, liver, spleen and kidney. These organs were pulverized and sterilized in the same manner as slime.

Table I lists the results obtained with the use of different media. The data show certain differences in the intensity of development of the parasite, depending on the type of medium employed.

Ichthyophthirius was found to develop fairly intensely on media based on slime with the addition of gill tissue; when skin, muscle or spleen were added, the development was much slower. Media containing kidney and liver produced an insignificant growth of the parasites. The average maximum development under given conditions was recorded after seven to nine days.

Table I

Comparison of intensity of development of *Ichthyophthirius multifiliis* on various media

Medium	Turbidity	Intensity of tomit development after					
		1 day	3 days	5 days	7 days	9 days	11 days
Slime	Weak	+	+ + +	++ + +	+++++	+++++	+++
Gills	Weak	+	++	+++	++++	+++	++
Skin	Medium	+	++	++	+++	++	+
Flesh	Strong	-	+	++	++	+	+
Liver	Very strong	-	-	+	+	+	-
Spleen	Strong	-	+	+++	++	++	+
Kidney	Very strong	-	+	-	-	-	-

N.B.
+ = single individuals 1-2 in the field of vision
++ = small number 2-5 " " "
+++ = medium number 5-10 " " "
++++ = large number 10-15 " " "
+++++ = very large number 15-25 " " "

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INFECTIOUS SWIM BLADDER DISEASE OF THE COMMON CARP

by

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Abstract

A new severe disease of the common carp, encountered in many fish ponds in Poland causes heavy mortalities, especially of yearlings. Brown concretions on the middle layer of swim bladder are characteristic of the disease. In chronically affected fish, apart from considerable changes in swim bladder walls, the formation of a great peritoneal cyst follows. The economic significance of this disease is often greater than of carp dropsy. The etiology of the disease is being studied.

MALADIE INFECTIEUSE DE LA VESSIE NATATOIRE DE LA CARPE COMMUNE

Résumé

Une nouvelle et grave maladie de la carpe commune, entraînant de fortes mortalités, notamment chez les sujets d'un an, est apparue dans de nombreux étangs de pisciculture en Pologne. Elle se caractérise par la formation de concrétions brunes sur la couche médiane de la vessie natatoire. Chez les sujets atteints de maladie chronique, on note, outre une altération considérable des parois de la vessie natatoire, la formation d'un grand kyste du péritoine. Du point de vue économique, cette maladie est souvent encore plus redoutable que l'hydropisie. L'étiologie de la maladie est actuellement étudiée.

LA ENFERMEDAD INFECCIOSA DE LA VEJIGA NATATORIA DE LA CARPA COMUN

Extracto

Una nueva y grave enfermedad de la carpa común, observada en muchos estanques piscícolas de Polonia, causa grandes mortandades, especialmente entre los jaramugos de un año. Una característica de la enfermedad es la aparición de concreaciones pardas en la capa media de la vejiga natatoria. En los peces afectados crónicamente, aparte los cambios considerables en las paredes de la vejiga natatoria, sigue la formación de un gran quiste en el peritoneo. La importancia económica de la enfermedad es frecuentemente mayor que la causada por la hidropesía de la carpa. Se está estudiando la etiología de la enfermedad.

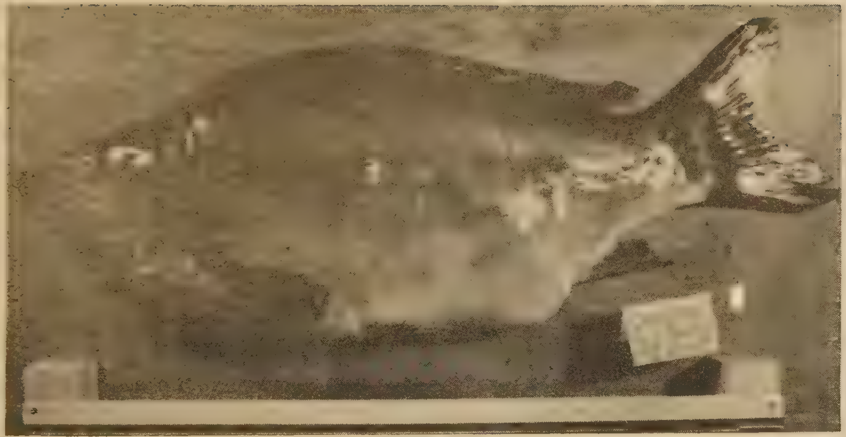

Fig. 1 Change in body shape of carp with infectious swim bladder disease

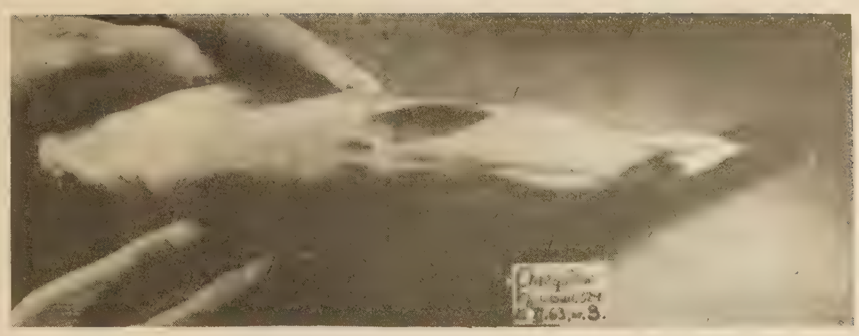

Fig. 2 Vertical view of carp swollen with swim bladder disease

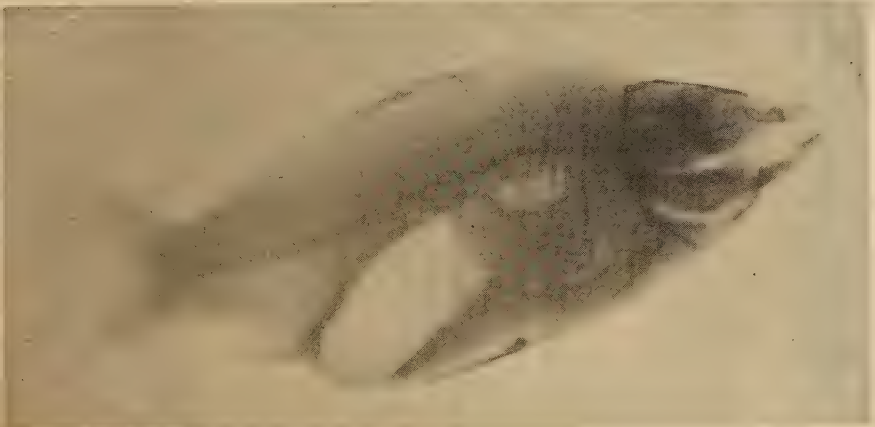

Fig. 3 X-ray photograph of a carp with swim bladder disease. Note large air cyst formed in the abdominal cavity and reduced size of anterior part of the swim bladder

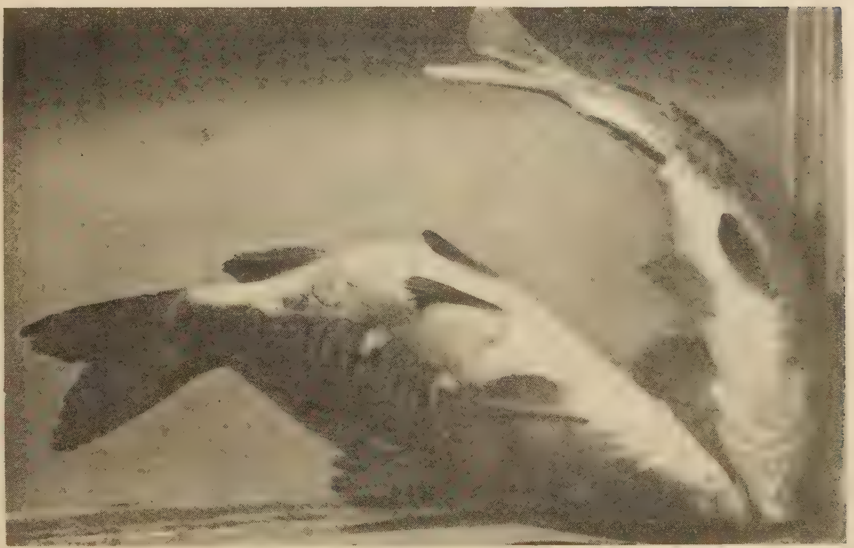

Fig. 4 The resting position in carp with swim bladder disease, related to the presence of the air cyst in the body cavity.

This carp disease was only recently found in Poland (Markiewiez, 1966a and b) but is spreading widely and causing heavy losses. It has also been observed in the Soviet Union (Shpolanskaia, 1963; Gevkan et al., 1966) and Hungary (Ivasik, personal communication). Yearling carp are more acutely affected than older fish, and losses among yearlings are greater. In ponds in south Poland supervised by the Krakow Fish Disease Laboratory losses due to this disease often reach 50-70 percent. Among the older fish more than 5 percent show the pathological changes due to the disease, the two and three year old fish affected becoming swollen and swimming upside down, the abdomen being characteristically deformed near the anal fin (Figs. 1 and 2).

The pathological changes start with inflammation of the peritoneum surrounding the swimbladder. This symptom also occurs in fish injected with the filtrate from ground-up swimbladders showing pathological changes, and in this case a serous liquid develops under the peritoneum.

A typical symptom formed incourse of this disease is the appearance of a large number of brown-coloured concretions in the middle layer. The swimbladder walls become thickened, especially posteriorly, which may lead to complete privation of its air content.

In its chronic state the disease leads to the formation of a great air cyst, the walls of which are formed by the peritoneum. This cyst surrounds the posterior part, but also extends to the anterior part of the swimbladder. The cyst walls, originally thin, become thickened. The cyst contains a serum or blood-stained purulent liquid, often with a gelatinous mass floating in it. Cyst formation may be followed by a decrease in size of the anterior part of the swimbladder, clearly visible from the X-ray photograph (Fig.3).

The formation of the cyst lowers the fish's centre of gravity so the diseased fish rests belly upwards (Fig. 4), only righting itself when disturbed.

The etiology of the disease needs further study and investigations based on artificial infections are in progress.

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IX/E-6

INFECTIOUS GILL NECROSIS OF CARP

by

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Abstract

This report concerns a new disease of all age groups of carp, often causing considerable mortalities throughout the year. A great proportion of diseased fish loses parts of the gill tissue due to mortifying of their lamellae. A chronically diseased fish is inhibited in its growth. The etiology of this disease which has considerable significance in fish farming in Poland is being further studied.

NECROSE INFECTIEUSE DES BRANCHIES DE LA CARPE

Résumé

Cette communication traite d'une nouvelle maladie atteignant les carpes de tous groupes d'âge et causant souvent une mortalité considérable à toute époque de l'année. Une forte proportion des poissons malades perdent une partie du tissu de leurs branchies par suite de la mortification des lamelles. Un poisson atteint de maladie chronique est retardé dans sa croissance. L'étiologie de cette maladie dont l'importance est considérable dans la pisciculture polonaise fait l'objet d'études plus approfondies.

NECROSIS INFECCIONSA DE LAS BRANQUIAS DE LA CARPA

Extracto

Esta memoria se ocupa de una nueva enfermedad de todos los grupos de edades de carpa que causa mortandades considerables durante todo el año. Una gran proporción de los peces atacados de esta enfermedad pierden parte de su tejido branquial por la pérdida de vida de sus laminillas. Se observa una inhibición del crecimiento en los indivíduos atacados crónicamente. Está estudiándose más a fondo la etiología de esta enfermedad que tiene importancia considerable en el cultivo de peces en Polonia.

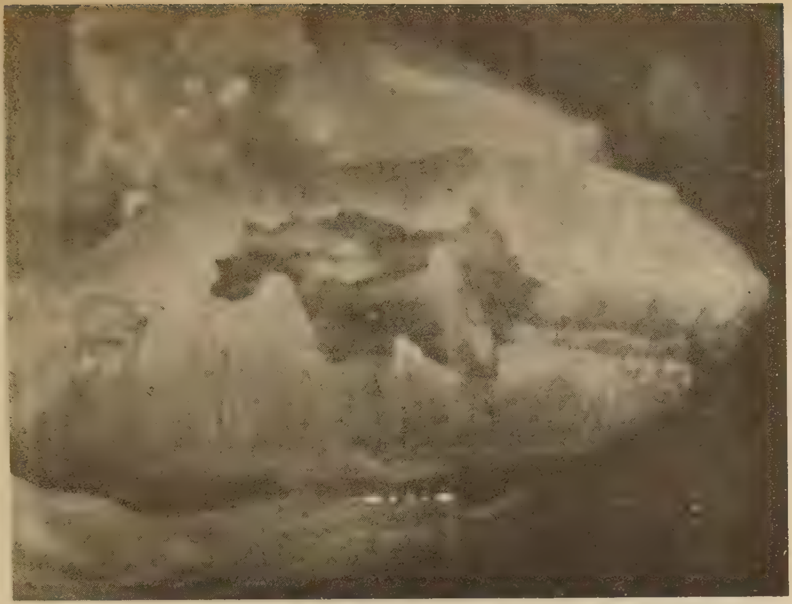

Fig. 1 Gills of carp damaged by infectious gill necrosis

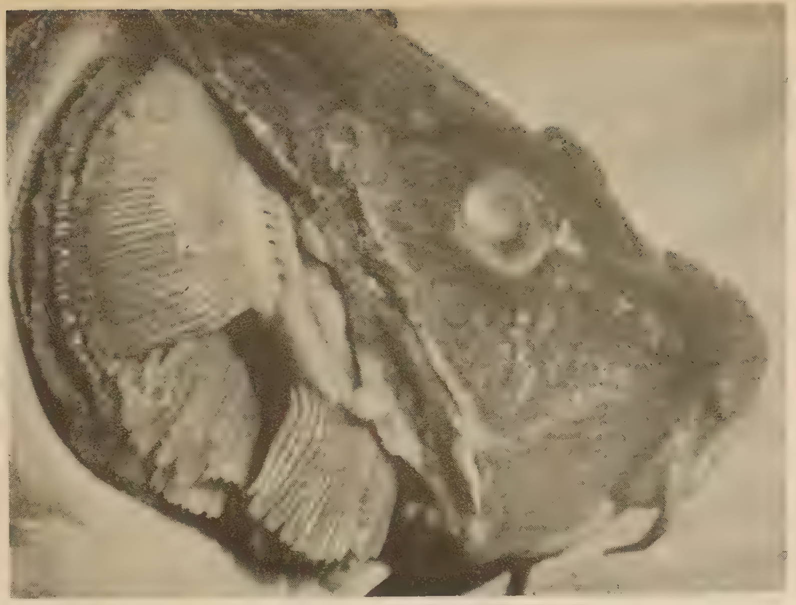

Fig. 2 Gill losses due to infectious gill necrosis

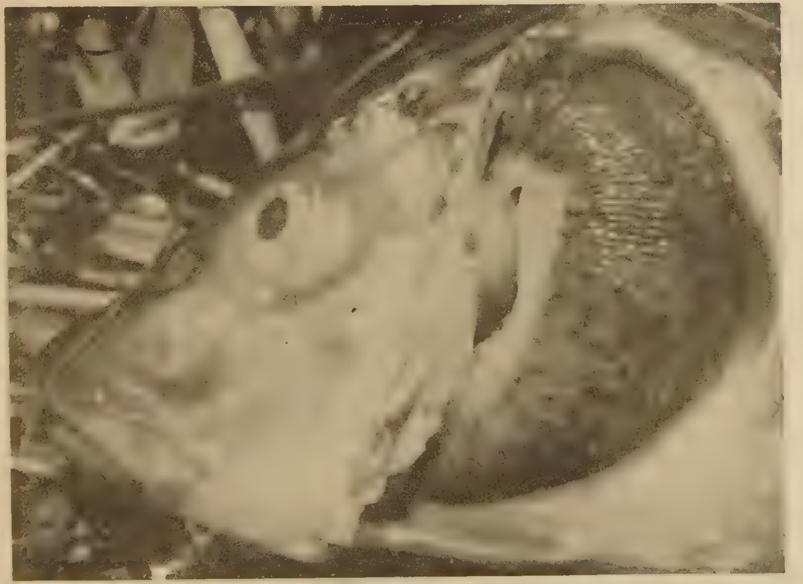

Fig. 3 Nodular thickenings of gill lamellae due to branchiomycosis. Note the very different picture from that caused by infectious gill necrosis (Fig. 4)

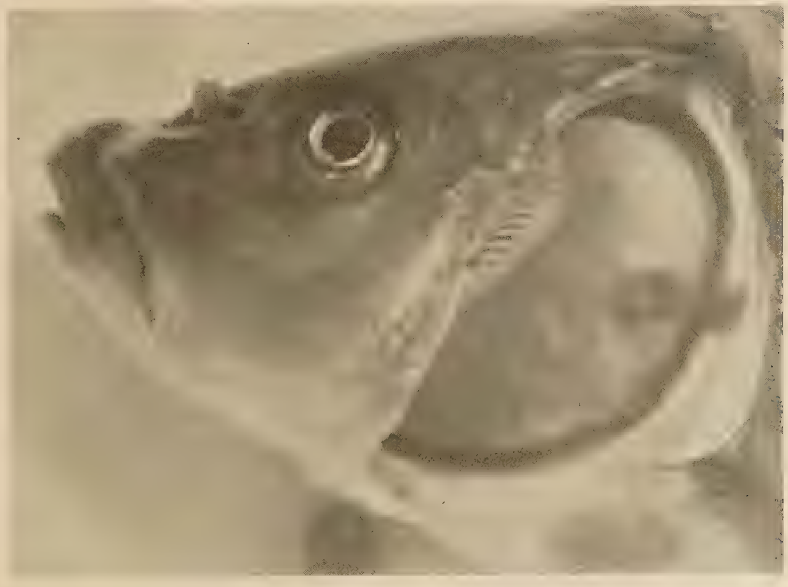

Fig. 4 Necrosis of the ends of the lamellae caused by infectious gill necrosis. Some cysts of *Myxobolus* shine through

(All photographs by the author)

The disease called infectious gill necrosis of carp recently aroused great interest in Polish fish farms. In the course of this disease an extended gill necrosis develops and in consequence often wide gill losses occur (Fig. 1, 2). This is reminiscent to a certain degree of the changes related to branchiomycosis, caused by the Branchiomyces sanguinis fungus. However, in this disease there is no infection of fungus and also the anatomo-pathological picture of the gill necrosis is different. The thickenings of the lamellae (Fig. 3), caused by fungus plugging the vessels, are lacking here, while the ends of the lamellae (Fig. 4) or even the whole lamellae become anaemic and mortify. In the intermediate stage agglomerations (Fig. 5) of fine cell elements in the lamellae tissue are visible,as a result of which the outer parts of the lamellae become thickened (Fig.6). In addition, as opposed to branchiomycosis, this disease is not limited to summer or autumn but appears at any time of the year. This disease differs also from myxobolosis, mucophilosis and other parasitic diseases such as dactylogyrosis and gyrodactylosis. No relation between the gill necrosis described here and the carp abdominal dropsy was proved, although both these diseases as well as other diseases may sometimes occur simultaneously.

The morbid changes may affect a considerable part of the fish stock. In four years of continuous investigation at the Experimental Fish Farm "Przereb" of the Zootechnical Institute at Zator the percentage of fish with losses of gill tissue averaged 20.5 percent and rose to 48.1 percent (Table I).

Table I

Results of gill examinations in carp from Przereb fish farm

Pond	Number of fish examined	Number of fish with gill losses	Percent of fish with gill losses
G	718	93	13
M	410	148	34.6
K	79	38	48.1
J	603	261	43.3
P	496	100	20.2
L	1016	105	10.3
Total	3408	699	Average 20.5

While inspecting fish in order to assess the loss of gills the question arose as to whether the disease affects the rate of fish growth. It was demonstrated that in three size groups of fish in two ponds, gill losses were highest amongst the smallest fish (Table II).

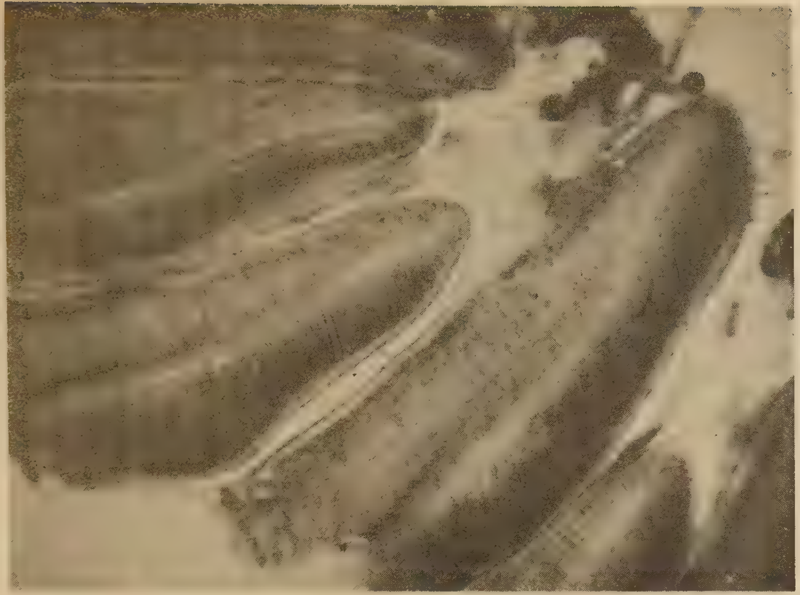

Fig. 5 Agglomerations of cells in the course of infectious gill necrosis

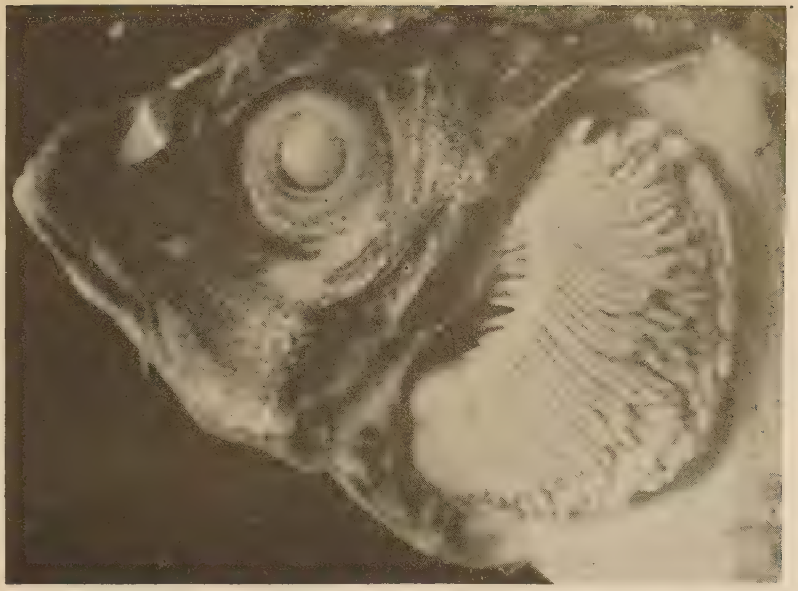

Fig. 6 The thickening of gill lamellae which often grow together in infectious gill necrosis

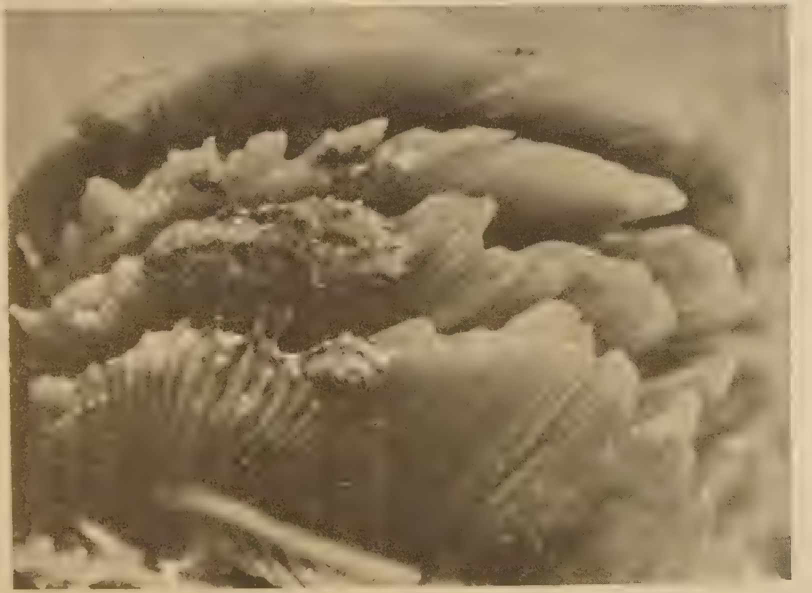

Fig. 7 Intense gill necrosis. Parts of the gills destroyed by secondary saprolegnia infection

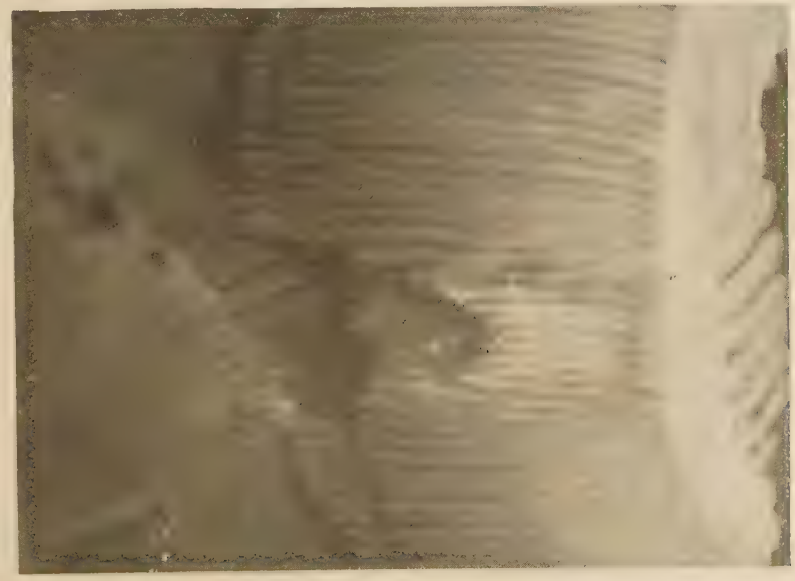

Fig. 8 Gill necrosis and gill losses

(All photographs by the author)

Table II

Gill losses and size of carp

Pond	Size group of fish	No. of fish examined	No. of fish with gill losses	Percent of fish with gill losses
M	small	83	59	71.0
	medium	210	55	26.2
	large	117	28	23.9
J	small	40	28	70.0
	medium	295	136	46.1
	large	268	97	36.2

The decrease of growth rate depends on the period in which the disease develops. The earlier it attacks the fish, the more pronounced are its effects on the growth. If the disease develops in the later part of the growth season, it will result in a rather small retardation of the growth rate in spite of sometimes great changes in the gills.

The disease is usually mild, but an acute form can occur, and death follows as a result of an extended necrosis of the gill lamellae (Fig. 7). An anaemia, especially of the ends of the lamellae, has been observed when a fairly mild form of the disease occurs. The gill lamellae mortify and then, after the gill tissue falls off, extended gill losses sometimes follow (Fig. 8).

This disease affects carp of all ages.

A precise knowledge of the etiology of infectious gill necrosis would be of great value since it brings about retardation of growth rate and increases mortality of carp. Therefore further studies on this disease are being carried out by the author.

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AN ATTEMPT TO CONTROL DACTYLOGYROSIS OF CARP WITH NEGUVON

by

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Abstract

The authors used one percent aqueous solution of Neguvon in the form of a bath to control a mass invasion of Dactylogyrus vastator Nybelin in carp fingerlings of 3.1 to 5 cm length averaging 1.3 g in weight. The bath lasted 15 to 20 minutes. The treatment was given to 6,450 fingerlings. No losses were recorded either in the course of the bath or later. A complete eradication of the parasite was achieved. The parasite-conditioned changes on the gills disappeared and there was considerable improvement in the health of the fish.

It has been observed that the Neguvon solution should be prepared immediately before use. If prepared on the previous day it develops toxic properties.

ESSAI DE LUTTE CONTRE LA DACTYLOGYROSE DE LA CARPE A L'AIDE DE NEGUVON

Résumé

Les auteurs ont utilisé des bains de Neguvon en solution aqueuse à 1 pour cent pour lutter contre une invasion massive de Dactylogyrus vastator Nybelin chez des alevins de carpes de 3,1 à 5 cm de longueur totale, et pesant en moyenne 1,3 g. Le bain avait une durée de 15 à 20 minutes. Ce traitement a été appliqué à 6450 alevins. Aucune perte n'a été enregistrée, ni au cours du bain ni ultérieurement et les parasites ont été complètement éliminés. Les altérations des branchies d'origine parasitaire ont disparu, et la santé des poissons s'est considérablement améliorée.

Il a été constaté que la solution de Neguvon devait être préparée immédiatement avant l'usage. Si on la prépare le jour précédent, elle devient toxique.

INTENTO PARA COMBATIR LA DACTILOGIRIASIS DE LA CARPA CON NEGUVON

Extracto

Los autores emplearon una solución acuosa de Neguvon al uno por ciento, en forma de baño contra la invasión de Dactylogyrus vastator Nybelin, con crías de carpa de 3,1 a 5 centímetros de longitud total y 1,3 gramos de peso medio. El baño duró de 15 a 20 minutos. Fueron tratadas 6.450 crías. Ni durante el baño ni después de él se registraron pérdidas. Se consiguió la destrucción total de los parásitos. Desaparecieron los trastornos de las agallas determinados por el parásito y el estado de salud de los peces mejoró considerablemente.

Se ha observado que la solución de Neguvon debe prepararse inmediatamente antes de usarla. Si se prepara el día anterior adquiere propiedades tóxicas.

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In Poland dactylogyrosis of carp (Cyprinus carpio) is usually controlled by an early transfer of fingerlings from fry ponds to fingerling ponds to thin out the fish stock. Apart from this the ponds are disinfected and the carp spawners are subjected to a preventive bath in NaCl solution. Frequently, however, there is a need of an immediate control of dactylogyrosis in fry, and to this end also a bath in NaCl solution is employed. This measure, however, has only a slight effect on the parasites, whereas at higher concentrations it affects the small fingerlings. Hence the need of more effective chemical agents.

Encouraging results obtained in the control of parasites of domestic animals by means of organic phosphorous compounds attracted the attention of fish breeders to these compounds.

In recent years attempts have been made to use Neguvon, a Bayer product, as well as similar compounds Dipterex and Trichlorphon to control fish parasites (Imori, 1959; Bailösoff, 1963; Schäperclaus, 1963; Sarig, Lahav and Shilo, 1965).

Bailösoff and Schäperclaus used the chemical at a high concentration (2 to 2.5 percent) for short baths, whereas Sarig et al. applied a very low concentration (0.8 ppm) in a pond where the chemical acted for a longer period, eradicating the parasites but causing no harm to the fish.

Encouraged by the promising results obtained by the above-mentioned investigators with Dactylogyrus vastator Nybelin, the authors used a bath in an aqueous Neguvon solution in a case of an intensive invasion of Dactylogyrus vastator in one of the fish farms near Olsztyn.

A pond of one ha area stocked with 10,000 fingerlings, which at the time of invasion measured 3.1 to 5 cm total length and weighed 0.4 to 2.4 g (average 1.3 g), was invaded by the parasites in the first ten days of August 1965. Almost simultaneously mass mortality ensued. The fingerlings were emaciated, showed a retarded growth, and did not take food. The gills were pale, sticking together, with hyperplasia of the epithelium and large amounts of slime. The intensity of the invasion was 20 to 50 parasites per gill arch. The parasites reproduced intensively; numerous eggs and larvae in different stages of development were observed.

Up to the day on which the bath was applied some 40 percent of the stock had died.

Since immediate action had to be taken, the authors decided upon a short bath using a high concentration of Neguvon according to Bailösoff's method.

Previous to the application on the farm, numerous experiments were made in aquaria to examine the effect of this chemical on the parasites and also on fishes under existing local conditions.

In baths of 0.5, 1, 2 and 2.5 percent Neguvon concentrations, and at temperatures from 19 to 25°C, the fish behaved normally for 20 to 75 minutes (the weaker the solution the longer), then they swam to the surface and lay on their side. After transferring them to fresh water they regained their balance and remained alive showing no visible changes.

At all mentioned Neguvon concentrations the parasites failed to move and had already contracted with protruded pharynxes after a five-minute bath. An examination 24 hours after the bath showed a few (one to three parasites per fish) feebly moving trematodes. Three days later no more parasites could be found on the treated fish, the gills regained their normal appearance, and slime and hyperplasia of the epithelium disappeared.

In view of the successful results obtained in aquaria, the fingerlings on the farm were subjected to a bath in a 1 percent aqueous solution of Neguvon for 15 to 20 minutes. This treatment was given to 6,450 fingerlings in four lots in a 50-litre tub without once changing the solution.

After the water was drained away and the fingerlings removed, the pond was disinfected with chloramine.

The fingerlings were rinsed in running water where they remained until the following day. They were then transferred to the same pond. During the bath and also on the following day no losses of fish were noted.

A control examination a fortnight after the bath showed a considerable improvement in the condition of the fingerlings. The respective measurements at that time were: total length 5.6 to 7.7 cm, weight 2.7 to 7 g, (average 4.36 g). No more deaths were recorded, the fingerlings took food readily, and no disease symptoms were visible on the gills. At this time only single specimens of D. vastator were found on the gills. These may have hatched from the eggs that lay on the pond bottom and were not killed during the disinfection.

To judge from this successful experiment and also from the results of other authors, the chemical Neguvon shows great promise as a control agent against dactylogyrosis of carp. However, before introducing it as a routine treatment in fish culture, further experiments are necessary.

It should be stressed here that a fresh Neguvon solution of a high concentration should be prepared each time. When stored for a longer period the solution affects the fish. In the author's experiments, fingerlings put into a bath prepared on the previous day, the balance was disturbed after only seven to ten minutes; they took a vertical position with the head down and then swam near the surface putting their mouths out of the water and turning on their side. Transferred to fresh water, they failed to revive.

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EFFECT OF THE STRIGEID TREMATODE, *POSTHODIPLOSTOMUM MINIMUM*, UPON GROWTH AND MORTALITY OF BLUEGILL, *LEPOMIS MACROCHIRUS*

by

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Abstract

Studies were conducted to evaluate the effect of experimental infections of the digenetic trematodes, *Posthodiplostomum minimum*, upon growth and mortality of the bluegill, *Lepomis macrochirus*.

Growth of fingerling bluegill over a six-week period was not appreciably reduced when the fish were infected with an average of 103.3 metacercariae; however, average infection rates of 353.1 and 546.8 metacercariae per fish significantly reduced growth rates during a 32-week period.

Mortality rate of bluegill infected with an average of 353.1 metacercariae was more than twice that of control fish over a 40-week period.

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EFFET DU TREMATODE STRIGEIDE, POSTHODIPLOSTOMUM MINIMUM SUR LA CROISSANCE ET LA MORTALITE DU BLUEGILL, LEPOMIS MACROCHIRUS

Résumé

Des études ont été faites pour tenter d'évaluer l'effet d'infections expérimentales de trématodes digénétiques, *Posthodiplostomum minimum* sur la croissance et la mortalité du bluegill, *Lepomis macrochirus*.

La croissance d'alevins du bluegill, observée pendant une période de six semaines, n'a pas été sensiblement réduite lorsque les poissons étaient infectés avec une moyenne de 103,3 métacercaires ; toutefois, avec des taux d'infection moyens de 353,1 et 546,8 métacercaires par poisson, on a constaté un ralentissement marqué des taux de croissance au cours d'une période de 32 semaines.

Le taux de mortalité des Bluegill infectés avec une moyenne de 353,1 métacercaires était deux fois plus élevé que celui des poissons témoins au cours d'une période de 40 semaines.

EFECTOS DEL TREMATODO POSTHODIPLOSTOMUM MINIMUM EN EL CRECIMIENTO Y MORTALIDAD DE LA CARPA LEPOMIS MACROCHIRUS

Extracto

Se llevaron a cabo estudios para evaluar el efecto de las infecciones experimentales en los trematodos digenéticos *Posthodiplostomum minimum* sobre el crecimiento y mortalidad de la carpa *Lepomis macrochirus*.

El crecimiento de las crías de carpa en un período de seis semanas no se vió apreciablemente reducido cuando se infectó al pez con un promedio de 103,3 metacercarias; sin embargo, unas tasas medias de infección de 353,1 y 546,8 metacercarias por pez hicieron disminuir sensiblemente las tasas de crecimiento durante un período de 32 semanas.

La tasa de mortalidad de la carpa infectada con un promedio de 353,1 metacercarias fué más del doble que las de los peces testigos a lo largo de un período de más de 40 semanas.

1 INTRODUCTION

Metacercariae of the digenetic trematode, Posthodiplostomum minimum, commonly known as the white liver grub, encyst in the visceral organs of 97 species representing 18 families of North American fresh-water fishes (Hoffman, 1958). The life history of the parasite, in which a fish serves as the second intermediate host, has been described by Ferguson (1938) and Miller (1954). Several aquatic birds, notably the great blue heron, Ardea herodias, serve as definitive hosts; snails of the genus Physa serve as first intermediate hosts.

Many observations have been made regarding the high intensity of natural infections with P. minimum in visceral organs of several fishes, including the bluegill, Lepomis macrochirus, (Hunter, 1942; Sindermann, 1953; Lewis and Nickum, 1964). Relatively high numbers of the large metacercariae in certain vital organs led to much speculation on the effect of the parasite upon the functional state of fishes.

Studies were begun at Auburn University in 1962 to determine the effects of experimental infections of P. minimum upon the bluegill. A major objective was the determination of the effect of the parasitism upon growth of this important pond fish. Observations were made also on comparative mortality rates of parasitized and parasite-free fish.

2 MATERIALS AND METHODS

2.1 Experimental fish

In order to provide parasite-free fish, bluegill fry were seined from a bass-bluegill pond and stocked in plastic-lined pools. The fry fed on natural food in the fertilized waters. After two months the fish had attained total lengths of 4 to 8 cm and were of adequate size for use in experimental infections with P. minimum. Examination of 100 fish indicated that all were free of naturally encysted metacercariae of P. minimum.

Approximately 1,000 bluegills were obtained from the Eastaboga State Fish Hatchery in Alabama. The fish were 6 to 9 cm in total length. Hatchery records indicated that they were approximately six months of age. Examination of the viscera of a large sample of bluegills showed that the fish did not contain metacercariae of P. minimum.

2.2 Production of infected snails

Day-old chicks were infected with P. minimum as described by Ferguson (1938). Droppings containing parasite eggs were collected in pans of dechlorinated tap water and added to plastic-lined pools or to wooden troughs containing laboratory-reared physid snails susceptible to penetration by miracidia of P. minimum. After 60 days, snails were collected from the pools and troughs and sorted for those producing cercariae.

2.3 Experimental infection

The pool-reared bluegills were divided into groups of 10 and placed in 40-litre aerated aquaria. Each of seven aquaria received approximately 4,500 cercariae over a four-day period. The fish in seven aquaria were exposed to no cercariae, and served as controls.

The hatchery-reared bluegills were placed in groups of 200 in four wooden troughs 2.4 m x 0.6 m x 0.3 m. Each trough was filled to an average depth of 15 cm with dechlorinated tap water and fitted with aeration apparatus. Infection in each of two treatments was accomplished by adding approximately 25,000 cercariae over a three-day period. Six snails, each of which was producing approximately 1,000 cercariae daily, were suspended in each treatment trough in a nylon net for an additional five days. The nets were of a mesh size that would readily permit cercariae to pass, but would confine the snails.

In an attempt to produce a higher level of infection with P. minimum, one trough of hatchery-reared bluegills was exposed two months later to an additional 24 infected snails. The snails were allowed to remain in the nylon net for five days.

2.4 Growth studies

Growth studies were initiated after exposure of fish to cercariae. Each group of treated or control fish was maintained in a wooden trough previously described. Water temperature was maintained between 21°C and 27°C. Rate of flow was adjusted so that the water was changed in each trough approximately once per hour.

Fish were fed a commercial pelleted feed. The feeding rate was increased until all groups of fish were fed 4.5 percent of their body weight daily. Rations were added to the troughs in three equal portions between 8 a.m. and 5 p.m. This feeding program was continued for eight months, after which time the parasitized and control fish were subdivided each into equal lots. Subsequently, one-half of the parasitized fish and one-half of the control fish were continued on the 4.5 percent rate of feeding for two months. The remainder of each lot was reduced to a daily feeding rate of 0.5 percent of body weight. Throughout the 10-month period, the fish were weighed at bi-weekly intervals. Growth of experimental fish was followed by plotting average weight of bluegills from parasitized and control lots throughout the experiment.

2.5 Parasite counts

A minimum of 15 fish were sampled from each parasitized group to determine relative intensity of infection with P. minimum. Separate counts in each fish were made from the heart, kidney, liver, and other infected organs combined. Each organ or group of organs was placed in a separate test tube containing a pepsin solution prepared essentially as described by Hoffman (1955). The tubes were placed in an oven at 37°C for 15 minutes. The parasites, digested free from surrounding tissue, were counted in a grid petri dish with the aid of a stereoscopic microscope.

3 RESULTS AND DISCUSSION

3.1 Reaction of bluegills to penetration by cercariae of P. minimum

All fish exposed to cercariae of P. minimum exhibited characteristic reactions to the irritation produced by the penetration of parasites. They swam erratically through the water, often turning on their sides to rub themselves against the bottom or sides of the containers. While fish were resting, they exhibited rapid gaping of the mouth and flaring of the opercula. Tremors ran intermittently through their bodies. These characteristic actions began 30 seconds to 1 minute after introduction of cercariae into the water of the containers and persisted for 1 to 2 hours. After this period, exhausted fish rested listlessly near the surface or bottom of their containers with dorsal, anal, and pelvic fins clamped tightly against their bodies. This condition persisted for several hours; however, this behaviour could be interrupted temporarily by offering feed. Some of the reactions described above have been noted by others (Ferguson, 1938; Hunter and Hunter, 1940; Miller, 1954; Hoffman, 1958).

Close inspection of bluegills after exposure to large numbers of cercariae revealed numerous petechial hemorrhages in the musculature, especially in the dorsal and caudal regions. Hyperemia was noted at the bases of paired and median fins. Hoffman (1958) reported hyperemia in similar regions after infecting Pimephales promelas with a digenetic trematode related to P. minimum. During all experimental infections with P. minimum in this study, no fish died in aquarium experiments and only three died directly from heavy infections in trough experiments.

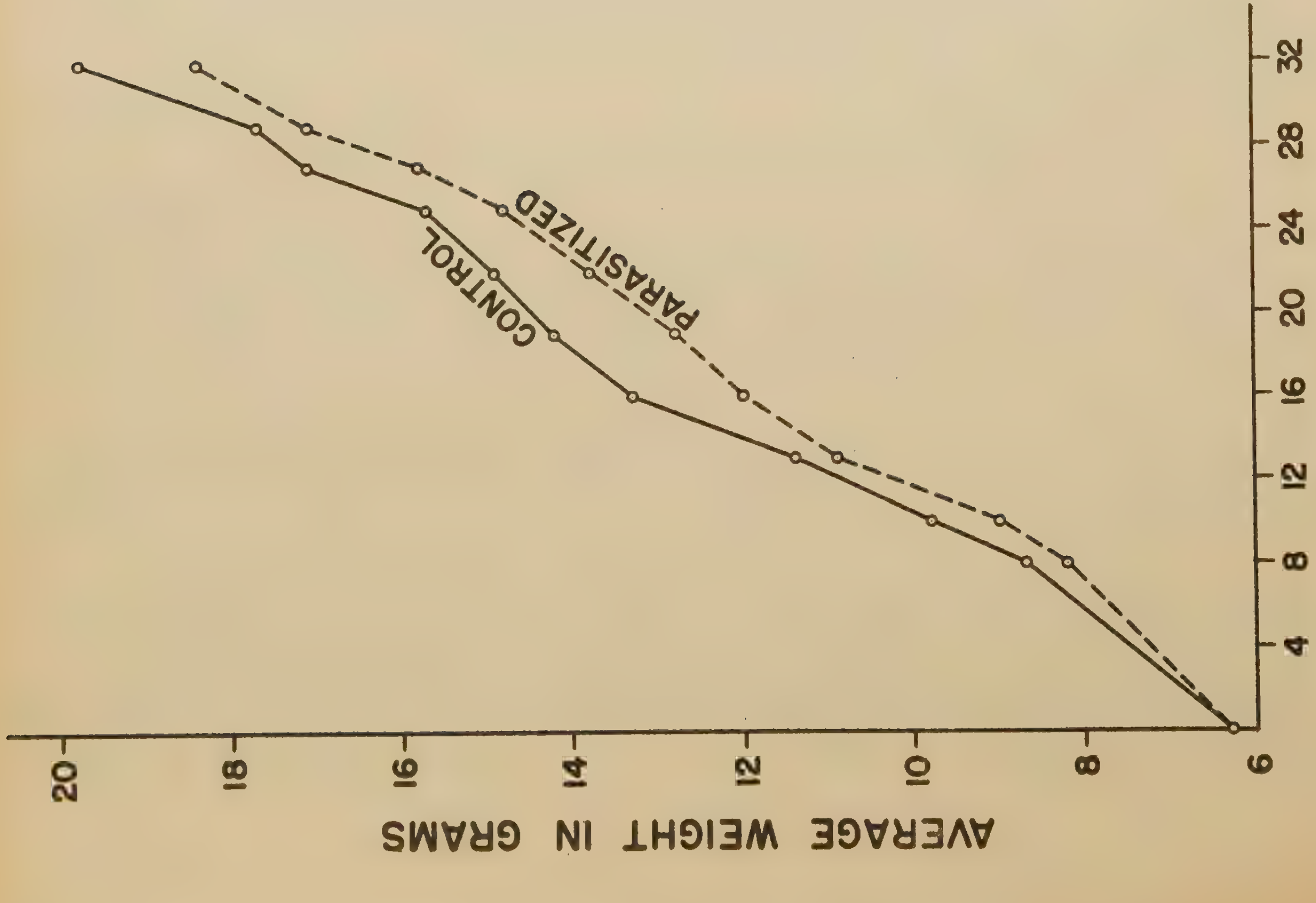

Fig. 1 Growth rate during a 32-week period

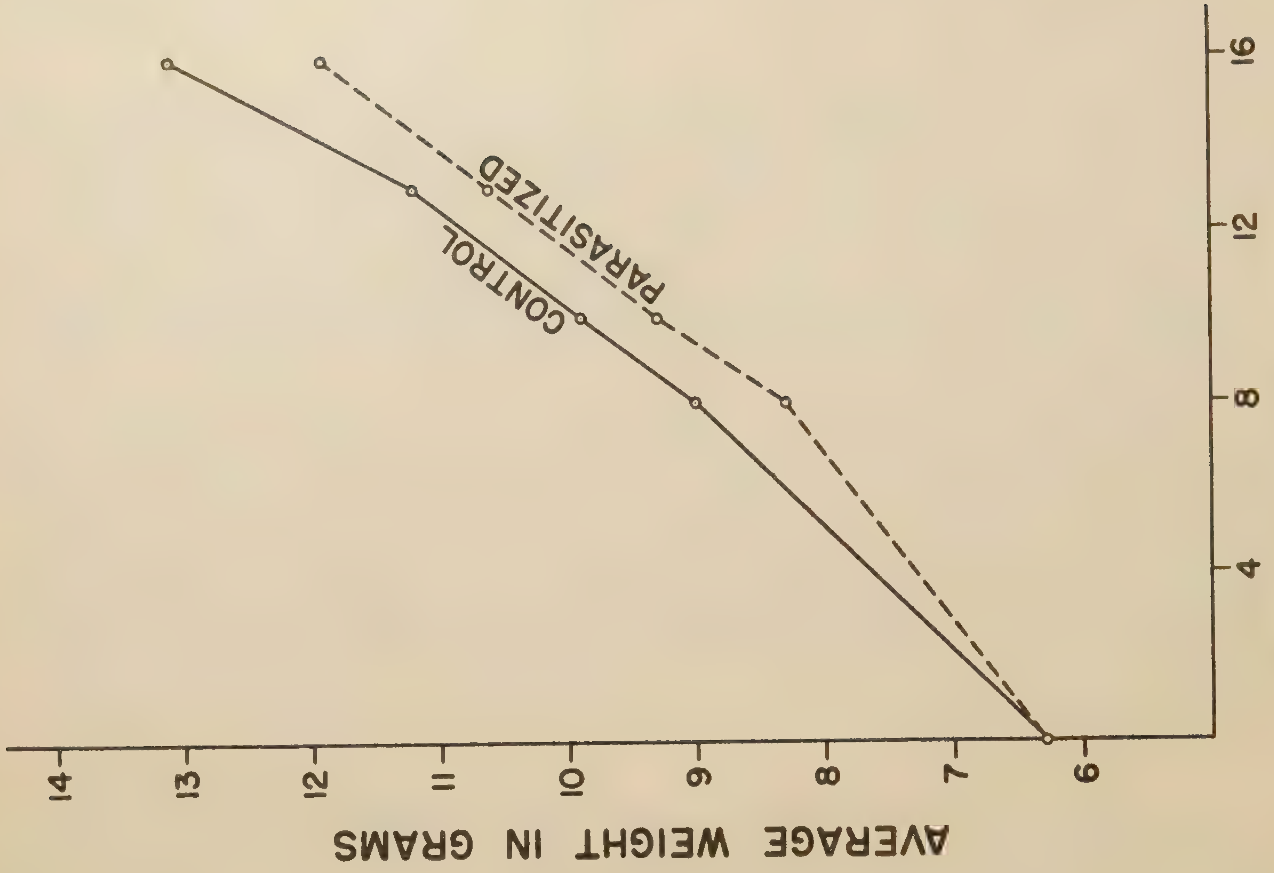

Fig. 2 Growth rate during a 16-week period

3.2 Intensity of infection produced

Counts of parasites 14 months after infection indicated that the fish exposed in aquaria to an average of 450 cercariae per fish contained an average of 103.3 metacercariae, of which 7.1 were located in the pericardium, 39.9 in the liver, 44.6 in the kidney, and 11.7 in the remaining visceral organs. Excepting the pericardium, liver, and kidney, the organs most commonly occupied by encysted parasites were the spleen, mesenteries, gonads, and an unidentified mass of lymphoid tissue located dorso-laterally to the oesophagus.

The bluegills exposed for a period of eight days in a wooden trough harboured an average of 353.2 parasites 13 months after infection. The pericardium contained 28.6; the liver, 142.5; the kidney, 99.8; and other organs, 82.3. One lot of fish, subdivided from this group and fed at a rate 0.5 percent of body weight per day for four months while others received feeding at 4.5 percent daily, yielded an average of only 264.2 parasites. A decrease in the number of metacercariae was evident in each organ with the exception of the heart. Only a single sample of 6 fish contributed to this average figure, and little evidence of dead or organized parasites was noted in histological preparations from these fish. The interesting possibility exists, however, that the number of P. minimum metacercariae was reduced when the host was subjected to a low level of nutrition. This might be interpreted as an expression of a well-adjusted host-parasite relationship.

Bluegills infected in a wooden trough and re-exposed for a five-day period two months later contained an average of 546.9 parasites. The pericardium harboured 59.1; the liver, 248.1; the kidney, 130.8; and other organs harboured 108.9 when counts were made 12 months after the original exposure.

3.3 Growth

Seventy pool-reared fish infected with an average of 103.3 parasites exhibited no discernible change in growth rate compared to 70 control fish over a 6-week period. A failure in water supply resulted in the death of the control fish after this time, but the parasitized fish were maintained at a moderate rate of feeding for 14 months. The fish grew well, many reaching sexual maturity.

Hatchery-reared bluegills infected with an average of 353.1 parasites grew at a rate which was significantly less than that of control fish throughout a 32-week comparison period (Fig. 1). Two hundred infected and 200 control fish averaged 6.3 g at the beginning of the experiment, but control fish had a greater average weight at each subsequent weighing period. At 16 weeks after infection, 170 parasitized fish averaged 12.0 g while 171 control fish averaged 13.3 g. One hundred and forty-six control fish weighed an average of 19.8 g, 1.4 g more than the average for 121 infected fish after 32 weeks.

Growth of fish infected with an average of 546.8 metacercariae of P. minimum was significantly less than was growth of control fish during a 16-week period (Fig. 2). At the end of this period, the average weight of 190 infected fish was 11.9 g and that of 190 control fish was 13.1 g. Growth comparison for this infection level was discontinued at this point because of the accidental loss of the majority of the parasitized lot.

General observations have been made by field biologists and parasitologists on the effect of parasitism on the growth in fishes. Sindermann (1953) stated that parasites of the internal organs are important to the fish, affecting growth and reproduction. Hubbs (1927) indicated that early growth was apparently retarded in a small cyprinid by heavy infection of the visceral organs by strigeid trematodes, resulting in a retention of larval characteristics and an increased number of scales in the lateral line. Krull (1934) reported that heavy experimental infections with Neascus amblopitus, which encysts in muscle, integument, and fins of host fish, produced arrested development in young common sunfish, Lepomis gibbosus. Cross (1934; 1935) made parasitological examination of perch, Perca flavescens, in conjunction with length-weight and aging studies. He found that fish of a particular age-class containing a heavy parasite fauna of cestodes, acanthocephalans, and strigeid trematodes had an average length and weight which was less than that for non-parasitized or lightly infected fish. Hunter and Hunter (1937; 1938) first attempted to ascertain experimentally the effect of a strigeid trematode upon its host. Eight fingerling smallmouth bass, Micropterus dolomieui, were infected with 193 to 708 metacercariae of Crassiphiala ambloplitis. After three months, there was a significant loss in the weight of infected fish as compared to five control fish. The loss in weight was attributed to disturbance of normal metabolism of the host fish by parasites encysted in the integument and fins. Petrushevskii (1957) presented data which indicated that high intensity of infection with metacercariae of Diplostomum spathecum reduced the growth rate of rainbow trout, Salmo gairdneri. The parasite encysts in the lens of the eye, and growth rate is reduced largely by impairment of vision resulting in inefficient foraging by the host. Bauer (1959) surveyed the American and Russian literature on fish parasites. He noted the wide distribution and considerable importance of D. spathecum in reducing growth in fishes cultured in Russian ponds. Fox (1962) reported little relationship between parasite incidence and host condition in trout from a Montana lake. Fish were naturally infected with varying numbers of nematodes, cestodes, acanthocephalans, and trematodes. Lewis and Nickum (1964) studied populations of bluegill which were naturally infected with P. minimum in numbers up to 1,035 per fish. They concluded that the metacercariae did not affect the plumpness of the fish.

The present study represents the first known attempt to determine the effects of experimental infections with P. minimum upon growth of the host fish. The results indicate that heavy infections could produce significant decreases in growth of bluegill sunfish. In the strictly natural environment the problem may not be so acute, but pond-cultural practices intensify the factors bringing about infection. Impoundment of water and increasing its fertility favour the production of snails which serve as first intermediate hosts for the parasite. Culture of bluegills increases their numbers per unit of water volume and thus favours penetration of cercaria into the fish, the second intermediate host. This concentration of fish also promotes predation by the great blue heron upon the bluegill and the completion of the life cycle.

3.4 Mortality

No figures were available on the mortality that might be expected to occur in bluegills held under laboratory conditions and handled frequently in weighing and measuring operations. It is well known, however, that bluegills are not so hardy as some of the other sunfishes. Swingle (1950) found that fingerling bluegills stocked in fertilized ponds suffered 15 percent mortality the first year and 19 percent the second year. During this study, daily observations were made to determine occurrence of mortality in parasitized and control groups. Particularly close attention was given on days immediately following the handling and weighing operations. Despite efforts to combat it, there was a mild chronic bacterial infection in both the parasitized and control lots of fish which occasionally resulted in the death of a fish.

A comparison of accumulated mortality data was made over the 10-month experimental growth period between the fish harbouring an average of 353.1 parasites and their controls. At the end of the period 47.4 percent of the parasitized fish had died, while only 22.5 percent of the control fish were lost. The latter figure is comparable to the mortality observed in fish stocked in farm ponds. This increase in mortality rate was apparently due to the decreased ability of parasitized fish to withstand the stresses of handling and weighing operations. It follows that parasitism by P. minimum in natural populations of bluegills might reduce the ability of the fish to adjust to extreme changes in environmental conditions, thus lessening their chances of survival.

4 SUMMARY AND CONCLUSIONS

Growth of fingerling bluegill over a six-week period was not appreciably affected by an average of 103.3 metacercariae per fish.

Growth of fingerling bluegill over a 32-week period was significantly reduced by an average of 353.1 metacercariae per fish.

Growth of fingerling bluegill over a 16-week period was significantly reduced by an average of 546.8 metacercariae per fish.

Mortality of fish infected with an average of 353.1 metacercariae was significantly greater than that of control fish during the 40-week period following infection.

While growth of bluegills infected with an average of 353.1 metacercariae was reduced approximately 10 percent over a 32-week period, mortality rates were 47.4 percent in the parasitized fish and only 22.5 percent in the control fish. It was concluded that parasitism at this level, not uncommonly found in nature, could significantly impair the ability of the bluegill to withstand other stresses of its environment.

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NEW CONTROL METHODS FOR *ICHTHYOPHTHIRIUS* IN PONDS

by

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Abstract

Channel catfish (*Ictalurus punctatus*) were used in experiments on the control of *Ichthyophthirius multifiliis* in glass aquaria and in earthen ponds. Four daily treatments with 1 ppm methylene blue [1] resulted in an average of 70 percent survival over the untreated controls. Two treatments with 2 ppm on the first and fourth days of the experiment resulted in 50 percent survival. All of the control fish were dead on the fourth day of the experiment.

A single earthen pond of 0.02 hectare stocked with 7,000 fingerling catfish was treated six times with 1 ppm methylene blue. Prior to the first application 2,150 fish died of a natural infection of *Ichthyophthirius*. The treatment resulted in 46.6 percent survival of the remaining population.

Experiments with 0.1 and 0.05 ppm malachite green [2] were conducted in aquaria to determine its efficacy for controlling *Ichthyophthirius*. Four replications of 10 fish each were used for each treatment. After 96 hours all of the control animals were dead; but there were no mortalities in any of the treated aquaria.

An earthen pond of 0.10 hectare containing heavily parasitized channel catfish was treated with 0.1 ppm malachite green. After the first day following treatment, no mortalities occurred. Nine days after treatment 25 fish were examined and found to be free of the infection. A sample of 200 fish from this population held in aquaria did not develop ichthyophthiriasis.

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[1] Methylene Blue A Extra Conc. supplied by Gen. Dyestuff Co., 4301 Rossville Boulevard, Chattanooga, Tennessee.

[2] Victoria Green S Extra Conc. supplied by Gen. Dyestuff Co., 4301 Rossville Boulevard, Chattanooga, Tennessee.

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NOUVELLES METHODES DE LUTTE CONTRE ICHTHYOPHTHIRIUS DANS LES ETANGS

Résumé

Des channel catfish (*Ictalurus punctatus*) ont été utilisés dans des expériences de lutte contre *Ichthyophthirius multifiliis* menées dans des aquariums de verre et dans des bassins en terre. Avec quatre traitements, à raison d'un par jour, au bleu de méthylène[1] en solution à 1 ppm on a obtenu, en moyenne, un taux de survie de 70 pour cent supérieur à celui enregistré avec les poissons témoins non traités. Avec deux traitements à 2 ppm, le premier et le quatrième jours, de l'expérience, on a obtenu 50 pour cent de taux de survie. Tous les poissons témoins étaient morts au quatrième jour de l'expérience. Un bassin en terre de 0,02 hectare, empoissonné à raison de 7 000 alevins (fingerlings) de catfish, a été traité six fois avec du bleu de méthylène à 1 ppm. Avant la première dose, 2 150 poissons étaient morts d'une infection naturelle d'*Ichthyophthirius*. Après traitement, 46,6 pour cent de la population restante a survécu. Des expériences avec des solutions à 0,1 et 0,05 ppm de vert malachite[2] ont été effectuées en aquarium pour déterminer l'efficacité de cette substance dans l'élimination d'*Ichthyophthirius*. Quatre groupes analogues de 10 poissons chacun ont été utilisés pour chaque traitement. Après 96 heures tous les animaux témoins étaient morts, mais il n'y a eu aucune mortalité parmi les poissons des aquariums traités. Un bassin en terre de 0,10 hectare contenant des channel catfish fortement infectés de parasites a été traité au vert malachite à 0,1 ppm. Après le premier jour de traitement, il n'y a plus eu de mortalité. Neuf jours après le traitement 25 poissons ont été examinés et on a constaté qu'ils étaient tous exempts d'infection. Un échantillon de 200 poissons a été prélevé parmi cette population et transféré en aquarium: aucun sujet n'a été atteint d'ichthyophthiriase.

NUEVOS METODOS PARA LA LUCHA CONTRA ICHTHYOPHTHIRIUS EN LOS ESTANQUES

Extracto

En los experimentos para combatir *Ichthyophthirius multifiliis* en acuarios de cristal y en estanques de barro se empleó bagre del canal (*Ictalurus punctatus*). Cuatro tratamientos diarios con 1 ppm de azul de metileno[3] dieron por resultado un promedio de supervivencia del 70 por ciento sobre los testigos no tratados. Dos tratamientos con 2 ppm en el primero y cuarto días del experimento determinaron una supervivencia del 50 por ciento. Todos los peces testigos habían muerto al cuarto día del experimento. Un estanque único de tierra de 0,02 hectáreas poblado con 7.000 crías de bagre, fué tratado seis veces con azul de metileno a 1 ppm. Con anterioridad a la primera aplicación, murieron 2.150 individuos de una infección natural de *Ichthyophthirius*. El tratamiento determinó una supervivencia del 46,6 por ciento de la población restante. Se realizaron experimentos en acuario con 0,1 y 0,05 ppm de verde malaquita[4] para determinar su eficacia para el control de *Ichthyophthirius*. Para cada tratamiento se efectuaron cuatro repeticiones de 10 peces cada una. Después de 96 horas, todos los animales testigos habían muerto; en cambio no se registraron mortandades en ninguno de los acuarios tratados. Un estanque de tierra de 0,10 hectáreas conteniendo bagres parasitizados intensamente, fué tratado con 0,1 ppm de verde malaquita. Al primer día siguiente al tratamiento no se registró ninguna muerte. Nueve días después del tratamiento fueron examinados 25 individuos comprobándose que estaban libres de infección. Una muestra de 200 peces de esta población mantenidos en acuarios no contrajo ictioftiriasis.

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[1] "Methylene Blue A Extra Conc." fourni par Gen. Dyestuff Co., 4301 Rossville Boulevard, Chattanooga, Tennessee.

[2] "Victoria Green S Extra Conc." fourni par Gen. Dyestuff Co., 4301 Rossville Boulevard, Chattanooga, Tennessee.

[3] Azul de metileno A Extra Conc. suministrado por Gen. Dyestuff Co., 4301 Rossville Boulevard, Chattanooga, Tennessee.

[4] Verde Victoria S Extra Conc. suministrado por Gen. Dyestuff Co., 4301 Rossville Boulevard Chattanooga, Tennessee.

1 INTRODUCTION

The protozoan Ichthyophthirius multifiliis is perhaps the most common cause of mortality among warm-water fishes. It is world-wide in distribution and causes an annual loss of fish estimated to value about $1,000,000.[1] Many chemical treatments and management techniques have been used with varying degrees of success in aquaria, small pools and raceways to control this species. However, there has been no means of controlling it in ponds which cannot be drained and refilled. This paper presents results of experiments on the control of ichthyophthiriasis with methylene blue[2] and malachite green.[3]

2 METHYLENE BLUE

A culture of Ichthyophthirius was maintained on channel catfish, Ictalurus punctatus. Laboratory experiments were conducted in 40-litre aquaria with de-chlorinated tap water. Ten uniformly infected catfish were stocked in each aquarium. One treatment consisted of 1 ppm methylene blue each day for four days and the other of 2 ppm on the first and fourth days of the experiment. Untreated controls were maintained and each treatment was based upon survival of the test fish. The former treatment resulted in an average of 70 percent survival (60 to 90 percent) and the latter 50 percent (40 to 60 percent). All of the control fish were dead by the end of the fourth day of the experiment.

A single earthen pond of 0.02 hectare, stocked with 7,000 fingerling channel catfish, developed a natural infection of Ichthyophthirius. Prior to the first application of methylene blue, 2,150 fish died and were removed from the pond. The pond was treated with 1 ppm methylene blue each day for six days between April 19 and 24. On May 4, when it was drained, 2,264 fish were recovered. This treatment resulted in 46.6 percent survival of the population present at the time of the first application. Unfortunately, it was not possible to maintain an untreated control for this experiment. However, on the basis of laboratory data, when fish become heavily infected with this parasite, complete mortality of the population can be anticipated in the absence of treatment. This formulation of methylene blue was also successfully used to control Ichthyophthirius on rainbow trout (Salmo gairdnerii) and golden shiners (Notemigonus crysoleucas) in commercial hatcheries. Six applications of 1 ppm were applied to a spring-fed pond of 0.81 hectare which contained several thousand adult trout. The pond owner estimated a loss of less than 100 fish after the first application and no parasites could be found on a sample of fish examined microscopically at the end of the treatment period.

Aquaria tests were conducted to determine the toxicity of Methylene Blue A Extra Con. to fingerling carp (Cyprinus carpio) and bluegills (Lepomis macrochirus). Carp were exposed to 3.5 and 10 ppm of this compound for 213 hours with no resulting mortality. Bluegills were exposed to 3 and 5 ppm without significant mortality. An average of 20 percent mortality among bluegills occurred in three replications of 10 ppm.

3 MALACHITE GREEN

Experiments with 0.1 and 0.05 ppm malachite green were conducted in aquaria to determine the efficacy of this compound in controlling Ichthyophthirius on channel catfish fingerlings. Four replications of 10 fish each were used for each treatment. Untreated controls were maintained. After an exposure of 48 hours, a 1-litre sample of water was collected from the bottom of each aquarium and examined for cysts. An average of 12 cysts were recovered from the untreated controls; only one cyst was recovered from the 0.1 ppm treatment. After 96 hours of exposure, all of the fish in the controls were dead and no mortality occurred in any of the treated tanks. The 80 fish treated in this experiment were removed from the aquaria and placed together in a feeding tank. Three weeks' observation under these conditions did not show the development of a parasite population.

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[1] The Merck Veterinary Manual; Second Ed. Merck and Company Inc., Rahawy, N.J. P. 1411, 1961

[2] Methylene Blue A Extra Conc.

[3] Victoria Green S Extra Conc. supplied by Gen. Dyestuff Co., 4301 Rossville Bld., Chattanooga, Tennessee.

An earthen pond of 0.1 hectare containing heavily parasitized channel catfish fingerlings was treated with 0.1 ppm malachite green. Approximately 200 dead fish were removed from the pond on the day after treatment. Nine days after treatment, a sample of 25 fish was examined, of which two were found infected with trophozoites of Ichthyophthirius, but no further mortality occurred in the pond. When the pond was drained, 23 days after treatment, 3,000 fingerlings were recovered. A sample of 200 fish held in an aquarium did not develop ichthyopthiriasis and microscopic examination did not show any parasites.

This chemical has been recommended to a number of commercial producers when Ichthyophthirius was found on samples of channel catfish and golden shiners brought to this laboratory. Although detailed data on these treatments are not available, they were all apparently successful. Considerable caution should be taken in the use of this compound since its toxicity to various species of fish has not been determined. Preliminary tests indicate that bluegills suffer some mortality at concentrations in excess of 0.05 ppm malachite green, whereas channel catfish over 60 cm in length suffer no significant mortality at 0.1 ppm.

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THE BIOLOGY AND CONTROL OF THE ANCHOR WORM, LERNAEA CYPRINACEA [1]

by

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Abstract

Life history studies of the anchor worm, *Lernaea cyprinacea*, showed three naupliar and six copepodid developmental stages. The life cycle of this species was completed in 17 days at 28°C. Control experiments conducted in aquaria using the organo-phosphate insecticide Dylox eliminated anchor worms with treatments of 0.1-0.5 ppm (active ingredient) repeated at two-week intervals. Field tests with Dylox at the rate of 0.25 ppm active ingredient eliminated parasitic larvae with three-weekly treatments, but a few adult anchor worms survived even after four-weekly treatments at this rate. Plankton samples from the treated ponds indicated that Dylox had no apparent effect on phyto-plankton. Little effect was noted on micro-crustaceans and rotifers.

ETUDE SUR LA BIOLOGIE ET L'ELIMINATION DE LA LERNAEA CYPRINACEA [2]

Résumé

L'étude du cycle vital de la lernée, *Lernaea cyprinacea*, a révélé que celle-ci passait par trois stades nauplius et six stades copépodides de développement. Le cycle évolutif complet de cette espèce demande 17 jours, à la température de 28°C. Les

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[1] Research supported under South-eastern Co-operative Fish Parasite and Disease Project.

[2] Recherches menée dans le cadre de la South-eastern Co-operative Fish Parasite and Disease Project.

expériences menées en aquarium avec un insecticide organophosphaté, le Dylox, a permis d'éliminer les lernées avec des traitements à 0,1-0,5 ppm (ingrédient actif) répétés à intervalles de deux semaines. Des essais sur le terrain avec des solutions de Dylox à raison de 0,25 ppm d'ingrédient actif ont permis de détruire les larves parasitiques au bout de trois traitements hebdomadaires, mais quelques adultes ont survécu, même après quatre traitements hebdomadaires à cette dose. Des échantillons de plancton prélevés dans les étang traités indiquent que le Dylox ne paraît pas avoir d'effet sur le phytoplancton. Il ne semble guère avoir d'effet non plus sur les microcrustacés et les rotifères.

LA BIOLOGIA Y CONTROL DE LA LERNEOCERA *LERNAEA CYPRINACEA* [1]

Extracto

Los estudios del ciclo vital de la lerneócera *Lernaea cyprinacea* han mostrado tres fases naupliales y seis copepódidas. El ciclo vital de esta especie fue completado en 17 días a 28°C. Los experimentos para su supresión realizados en acuarios utilizando el insecticida fosfatado orgánico Dylox eliminaron la lerneócera con tratamientos de 0,1-0,5 ppm (ingrediente activo) repetidos a intervalos de dos semanas. Las pruebas de servicio con Dylox a razón de 0,25 ppm de ingrediente activo eliminaron las larvas parasíticas con tres tratamientos semanales aunque algunas de las lerneóceras sobrevivieron incluso después de cuatro tratamientos semanales a dicha proporción. Las muestras de plancton de los estanques tratados indicaron que el Dylox no tenía efecto aparente sobre el fitoplancton. Se observó algún pequeño efecto sobre los microcrustáceos y rotíferas.

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[1] Investigación apoyada con arreglo al Proyecto Sudoriental Cooperativo sobre Parásitos y Enfermedades de los Peces

1 INTRODUCTION

The anchor worm, Lernaea cyprinacea, is one of the most important parasites infesting bait and commercial species of fish in the Southeastern United States. With the initiation of the Southeastern Cooperative Fish Parasite and Disease Project in 1964, it was decided that control of the anchor worm should be one of the first problems to be investigated. Like other parasitic crustaceans, the anchor worm has a hard exoskeleton of chitin that renders most parasite control treatments ineffective. It was, therefore, necessary to become familiar with its various life history stages in the hope that they could be more easily controlled than the adults. Reports of control of anchor worms using the insecticide Dylox have been favourable. Therefore, this material was used in these experiments.

The use of Dylox as an agent to kill anchor worms was reported from Japan at the Tenth Pacific Science Congress, Honolulu, Hawaii (1961). Dylox or Dipterex, (0,0-dimethyl-2,2,2-trichloro-1 hydroxylethyl phosphonate) used at a rate of 0.2 ppm in ponds, was reported to kill both free-swimming and parasitic stages of Lernaea within three days without injury to the fish. Later reports from the United States (Ungmom and Raisovich, 1965) and Israel (Lahav, Sarig and Shilo, 1964) also indicate control of Lernaea using Dylox or Dipterex.

2 MATERIALS AND METHODS

Life history studies of Lernaea cyprinacea were conducted in the laboratory. Control experiments using the insecticide Dylox were conducted in aquaria in the laboratory and in ponds. Egg sacs were carefully removed from adult anchor worms, placed in embryological dishes, and incubated at a constant temperature. Observations were made, usually about every two hours with the aid of a dissecting microscope. To study the various non-infective stages, larvae were collected immediately after hatching and placed individually in a hanging drop on a cover slip and sealed in a depression slide. The first infective stage of the anchor worm was introduced into aquaria containing fish. The fish were later treated to recover the various larval stages, or were killed and examined under the microscope. Only goldfish were used in the tests. Field tests were conducted in earthen ponds 1/350 hectare in size. A 50 percent wettable powder form of Dylox was used and each dose was weighed in the laboratory just prior to treatment. All treatments are expressed as ppm active ingredient.

A Wisconsin-type plankton net was used to take plankton samples prior to treatments, and also three days, one week, and two weeks after treatments.

3 RESULTS AND DISCUSSION

3.1 Life history studies

Observations of the development of the anchor worm agree with those of Lahav and Sarig (1964) and Tidd (1937). Mature eggs incubated at 27° -28° C hatched within 24 hours. Immediately after hatching, individual larvae were placed on a cover slip in a hanging drop and sealed in a depression slide with petroleum jelly to prevent evaporation. The larvae in the hanging drops were observed to molt three to seven times before developing into the first copepodid or parasitic larval stage. The first copepodid stage was reached three days after hatching. All six of the copepodid stages reported by Tidd (1937) and Lahav and Sarig (1964) were obtained from fish heavily infested with larvae.

Eleven days elapsed from the time the first copepodid stage was introduced into aquaria containing fish until anchor worms could be seen projecting from the skin of the fish. Male larvae were observed mating with the embedded females at this stage, although

Table I

Average number of adults and relative abundance of infestive larvae found on goldfish after one and two treatments of Dylox

Treatment concentrations (active ingred.)	No treatment		1 treatment		2 treatments	
	Adults	Larvae	Adults	Larvae	Adults	Larvae
0	6.9	med.	---	---	---	---
0.1	---	---	1.7	heavy	8.3	med.-heavy
0.2	---	---	2.2	very light	0.7	very light
0.5	---	---	1.3	light-med.	0.6	very light
1.0	---	---	2.0	med.-heavy	1.2	eliminated

Note: Fish were infested with six mature anchor worms when stocked.

Table II

Average number of adults and relative abundance of infestive larvae found on goldfish after treatments with Dylox

Number of treatments*	1-week intervals		2-week intervals		No treatment	
	Adults	Larvae	Adults	Larvae	Adults	Larvae
0	---	---	---	---	4.8	light-med.
2	---	---	0	very light	---	---
3	0	0	0.3	0	---	---
4	0.08	0	---	---	---	---

*All ponds treated with 0.25 ppm (active) Dylox

Note: Fish were infested with an average of 7.4 mature anchor worms when stocked.

mating normally occurs only in the last copepodid stage. The male does not develop beyond the last copepodid stage. Egg sacs were observed about four days after the females were first detected and mature eggs were seen two days after the sacs appeared. At a temperature of 28°C there was a lapse of 17 days from the time the eggs hatched until one of the offspring produced mature eggs. Complete embryological development may take place within the egg sac while it is still attached to the female.

3.2 Control tests

Prior to the control tests, preliminary toxicity tests were conducted on goldfish to determine their tolerance to Dylox. Using standard bioassay procedures, the 96-hour LD_{50}, or the amount of material found to be lethal to half of the test fish in 96 hours, was 27 ppm Dylox. Total hardness of the water was approximately 50 ppm in both aquaria and ponds. Temperature in the aquaria was 27°-28°C and in the ponds from 23° to 28°C.

3.2.1 Control tests in aquaria

Heavily infested goldfish (Carassius auratus) were placed in 40-litre aquaria and after an adaptation period, Dylox was added at rates of 0.05, 0.1, 0.2 and 0.5 ppm active ingredient. Each level had three replications and three aquaria received no treatment. All untreated fish died within three weeks; also, fish in two of the three aquaria treated at 0.05 ppm died within three weeks. Both of these latter groups of fish had extremely heavy infestations of parasitic larvae on the skin and gills. In several cases there appeared to be an almost complete removal of epithelium, which was the apparent cause of death. At the beginning of the second week, all of the remaining fish showed symptoms of a larval infestation. A second treatment, using the same concentration, was applied to half of the remaining fish. Fish not receiving the second treatment died within a week, whereas all traces of anchor worms disappeared from fish receiving the second treatment.

3.2.2 Control tests in ponds

Two series of field tests were conducted in small earthen ponds 1/350 hectare in area. In the first test 10 infested goldfish were stocked in each of 10 ponds. Dylox was added at rates of 0.1, 0.2, 0.5, and 1.0 ppm active material. Two ponds received each of the above levels of treatment and two ponds received no treatment. Examination of some of the goldfish prior to stocking revealed an average of six mature anchor worms per fish. Five days after the first application of Dylox, a second treatment of the same concentration was applied to one of the two ponds treated at each level. The ponds were drained after two weeks and the goldfish placed in 1:4000 formalin solution to remove larval stages of anchor worms from the fish. A dissecting microscope was used to examine the fish for adult anchor worms and the solution for copepodid larvae. The abundance of larvae was recorded as light, medium or heavy (Table I). The untreated fish had about the same number of adult anchor worms as when stocked, but all treatments of 0.2 ppm or higher resulted in a substantial reduction in the number of adults. Copepodid larvae were eliminated only at the repeat treatment of 1.0 ppm. From this series of tests, it was concluded that more than two treatments were necessary and that they should be spaced farther apart.

Since centrarchids are occasionally infected with anchor worms, toxicity tests were conducted on the bluegill, Lepomis macrochirus, to determine its tolerance to Dylox. A 96-hour LD_{50} of 2.5 ppm for the bluegill indicated that a concentration of 1.0 ppm may be near the toxic limit for these fish; therefore a second series of field tests was conducted using 0.25 ppm for all treatments.

In the second series of tests, 15 goldfish infested with an average of 7.4 anchor worms per fish were stocked into each of seven ponds. Repeat treatments were applied at one and two-week intervals. One pond was drained after three-weekly treatments and two drained after four-weekly treatments. One was drained after two treatments at two-week intervals and one was drained after three treatments at two-week intervals. The other two ponds were untreated. The average number of adults and the relative abundance of the copepodid larvae are presented in Table II. These data show that Dylox used repeatedly at a rate of 0.25 ppm gives an effective control of anchor worms. It appears that more than two treatments are required to eliminate the copepodid larvae, and that a few adult anchor worms will survive even after four treatments. It should be pointed out here that in several of the ponds late-stage tadpoles of the bullfrog, *Rana catesbeiana*, were found to have several mature anchor worms attached. Since these tadpoles had legs already formed and were able to move from pond to pond, they may have been a source of reinfestation to the treated fish.

3.3 Effects of Dylox on plankton

The toxicity of Dylox to a species of *Daphnia* was determined in the laboratory. Concentrations of Dylox above 0.1 ppm immobilized *Daphnia* within one hour, although death did not occur until after the second day. In view of the effects of Dylox on *Daphnia*, it was assumed that there would be a drastic reduction of microcrustaceans in the ponds following treatment. This did not prove true since microcrustaceans were fairly abundant within three days after treatment. However, there were fewer microcrustaceans in the treated ponds than in the untreated ponds at the termination of the experiment. Dylox treatments had no apparent effects on the rotifer population or phytoplankton in the ponds.

4 SUMMARY

Life history studies on *Lernaea cyprinacea* agreed with other studies on this species in that there were three naupliar stages and six copepodid stages. Life cycle from egg to mature adult was completed in seven days at 28°C.

Complete elimination of anchor worms was achieved in aquaria using two treatments of Dylox at rates of 0.1 ppm to 0.5 ppm (active ingredient) applied two weeks apart.

Dylox treatments gave an effective control of anchor worms in ponds. Parasitic larvae were eliminated in ponds after three-weekly treatments of Dylox at 0.25 ppm (active ingredient), but a few adult anchor worms survived even after four treatments.

Dylox had little apparent effect on microcrustaceans in ponds and no apparent effect on rotifers or phytoplankton at rates of 0.25 ppm active ingredient.

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CONTROL OF SNAILS BY THE REDEAR (SHELLCRACKER) SUNFISH [1]

by

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Abstract

Biological control of two species of native pond snails, *Physa* sp. and *Lymnaea* sp., was attempted using the redear sunfish, *Lepomis microlophus* (Gunther). The feeding habits of redears were studied under varied conditions in aquaria. Snails alone were fed to redears at rates up to 8 percent of their body weight for seven days, and with few exceptions, all were eaten. When snails and midge (Chironomidae) larvae were fed at rates of 2 and 6 percent respectively, redears ate 73.3 percent of the snails offered. When the feeding rate of snails was doubled, fish ate 70 percent of the snails offered. Snails comprised 39.1 percent of the food eaten by redears when 16.6 percent of the available food consisted of snails and 83.4 percent consisted of dragonfly nymphs. When 28.6 percent of the food given consisted of snails, they made up 48.6 percent of the total food eaten. Snail populations in plastic pools containing soil and six species of aquatic plants were reduced 80.6 to 98.9 percent within one day following the introduction of redear sunfish. The stomach contents of 63 redear sunfish taken from natural waters sparsely populated with snails were analyzed. Snails comprised 8.5 percent of the contents of the 49 stomachs containing food.

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IX/E-11

UTILISATION DU REDEAR (SHELLCRACKER) SUNFISH [1] (LEPOMIS MICROLOPHUS) POUR L'ELIMINATION DES ESCARGOTS

Résumé

Le redear sunfish, Lepomis microlophus (Gunther), a été utilisé au cours d'expériences de lutte biologique contre deux espèces indigènes d'escargots d'eau douce, Physa sp. et Lymnaea sp. Les habitudes alimentaires des redears ont été étudiées dans diverses conditions en aquarium. Au cours d'expériences où les redears ont été alimentés en escargots seuls à raison de 8 pour cent de leur poids corporel par jour pendant sept jours, presque tous les escargots ont été mangés. Avec une alimentation composée d'escargots et de larves de moucherons (Chironomidae) à raison de deux et six pour cent respectivement, les redears ont mangé 73,3 pour cent des escargots. Lorsque la ration d'escargots a été doublée, les poissons ont mangé 70 pour cent de ceux-ci. Les escargots représentaient 39,1 pour cent des aliments consommés par les redears dans les cas où 16,6 pour cent de la nourriture disponible consistaient en escargots et 83,4 pour cent en nymphes de libellules. Lorsque les escargots représentaient 28,6 pour cent des aliments fournis, ils entraient pour 48,6 pour cent dans le total des aliments ingérés. Dans des bassins en plastique contenant de la terre et six espèces de plantes aquatiques, les populations d'escargots ont été éliminées dans les proportions de 80,6 à 98,9 pour cent en l'espace d'un jour après introduction de redear sunfish. Le contenu de l'estomac de 63 redear sunfish prélevés dans des eaux libres où les colonies d'escargots étaient rares a été analysé. Dans les 49 estomacs contenant de la nourriture, on a constaté que les escargots formaient 8,5 pour cent du contenu.

LUCHA CONTRA LOS CARACOLES MEDIANTE LA PERCA LEPOMIS MICROLOPHUS [2]

Extracto

Utilizando la perca Lepomis microlophus (Gunther) se intentó el combate biológico de dos especies de caracoles indígenas de los estanques, Physa sp. y Lymnaea sp. Se estudiaron los hábitos alimentarios de la mencionada carpa en distintas condiciones en acuarios. En primer lugar, diariamente durante siete días, se le proporcionó como alimento solamente caracoles en proporciones que llegaban al 8 por ciento de su peso corporal y con pocas excepciones fueron consumidos todos. Cuando se les proporcionó caracoles y larvas de mosquitos (Chironomidae) en la proporción del 2 y el 6 por ciento, respectivamente, las carpas consumieron el 73,3 por ciento de los caracoles suministrados. Cuando se duplicó la proporción de alimentación de caracoles, las carpas absorbieron el 70 por ciento de los mismos. Los caracoles representaron el 39,1 por ciento del alimento consumido por las carpas cuando el 16,6 por ciento del alimento disponible estaba constituido por caracoles y el 83,4 por ciento por ninfas de libélula. Cuando el 28,6 por ciento del alimento proporcionado consistía en caracoles, éstos representaban el 48,6 por ciento del alimento total absorbido. Las poblaciones de caracoles existentes en depósitos de plásticos que contenían suelo y seis especies de plantas acuáticas quedaron reducidas entre el 80,6 y el 98,9 por ciento en un solo día como consecuencia de la introducción de la carpa de referencia. Fueron analizados los contenidos estomacales de 63 carpas de esta especie tomadas de aguas naturales pobladas poco densamente con caracoles. Estos constituían el 8,5 por ciento del contenido estomacal de 49 estómagos con alimentos.

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[1] Tiré d'une thèse de Master of Science présentée à la Faculté de l'Université d'Auburn. Ces travaux ont été subventionnés par une bourse de recherche PHS, E-2478 (C-1) accordée par les National Institutes of Health, Public Health Service.

[2] Basado en una tesis para Maestro en Ciencias (Master of Science) para la Facultad de la Universidad de Aurburn. Esta investigación ha sido apoyada con la donación para investigaciones del Servicio de Sanidad Pública E-2478 (C-1) de los Institutos Nacionales de Sanidad, Servicio de Sanidad Pública.

1 INTRODUCTION

Various species of snails are intermediate hosts of most digenetic trematodes of man, fish and other animals. The most important trematodes from a medical viewpoint are the blood flukes causing schistosomiasis in man. These flukes are a major cause of human illness and mortality in many parts of Africa, Asia and South America. Trematodes have been considered most vulnerable while in the snail host, whose control has been therefore the object of a vast amount of research.

Foremost among the many control measures attempted has been the use of chemicals toxic to snails. However, it is very difficult to control snails without adversely affecting the production of fish that may be the major source of animal protein for people in endemic areas of schistosomiasis. An added disadvantage of chemical control is the expense involved and the necessity of periodic treatment. The use of snail-eating fish offers the possibility of a lasting, economical and safe means of control. This possibility has received scant attention, although many fish feed to a greater or lesser extent upon snails. Michelson (1957) stressed the lack of significant work in his review of the literature dealing with the biological control of snails.

Hora (1952) recommended the culture of the catfish, *Pangasius pangasius*, where snails are a problem. According to his own observations and those of others, snails predominated in the diet of this fish. According to Hey (1946), the European tench, *Tinca vulgaris*, "favours a diet of snails" and will eventually eliminate them in certain permanent waters. He also found that the African lungfish, *Protopterus*, can subsist in aquaria entirely upon snails. De Bont and De Bont Hers (1952) reported that dense snail populations were eliminated from a small pond and greatly reduced in another by the African fish, *Serranochromis macrocephala*. They did not, however, give any information about the number or weight of fish involved. Oliver-Gonzalez (1946) observed the guppy, *Lebistes reticulatus*, to be very abundant in certain regions of Puerto Rico where the schistosome vector, *Australorbis glabratus*, was previously abundant, but is now no longer found. He reported that guppies in aquaria fed upon both egg masses and snails. A preference seemed to exist for those egg masses containing young snails ready to leave the egg masses. These fish were also observed to feed readily upon cercaria released by snails in aquaria.

Although some fishes native to endemic areas of schistosomiasis feed upon snails, they have not exerted any appreciable control. The possibility of using an exotic species, therefore, merits consideration. The redear sunfish, *Lepomis microlophus* (Gunther), appears to have the greatest potential of fish native to the South-eastern United States for controlling snails. For many years this fish was called shellcracker because of its habit of breaking the shells of molluscs before eating them. The food habits of this fish have received little detailed study; however, they are frequently reported to be malacophagous. Huish (1957) described the stomach contents of 69 redears taken from Lake George, Florida. Snails were found in 92 percent of the 36 fish examined that contained food, and they comprised 74.4 percent of the total volume of food eaten. Chable (1947) reported that snails were important in the diet of redear sunfish only in streams. Of the 96 fish examined from streams, 83 contained food. Snails were found in 97.6 of these fish, and each contained an average of 8.1 snails. Of the 13 fish taken from lakes only six contained food. Snails occurred in 66.7 percent, with an average of 1.3 snails per fish.

2 TEST ANIMALS

The redears used in these experiments were obtained from the Agricultural Experiment Station ponds of Auburn University, placed in stainless steel troughs provided with running water, and treated for the control of disease and parasites. Treatment consisted of a one-hour exposure to 10 ppm potassium permanganate followed by a six-hour exposure to 15 ppm formalin. All aquaria and nets and pans used in handling fish in the laboratory were first disinfected with either chlorox or roccal.

Snails of the genera Physa and Lymnaea, midge larvae of the subfamily Tendipedinae, and dragonfly nymphs of the suborder Anisoptera were collected from ponds and streams in the vicinity of Auburn, Alabama. Dragonfly nymphs were obtained by dragging a scoop net along pond bottoms, while snails were hand-picked from submerged vegetation or pond bottoms. Midge larvae were collected with "multiple-plate samplers" described by Hester and Dendy (1962).

The cases containing midge larvae were scraped from the plates with a spatula into a bottle half-filled with water. This bottle was shaken vigorously to separate the cases from each other and to loosen as much debris as possible. The contents of the bottle were then poured into a metal pan with a screen bottom and washed. After being washed, the cases containing the midge larvae were spread on a screen stretched over a shallow pan that was completely filled with water. A gooseneck lamp was then placed about 3 inches (76.2 mm) above the screen, and under these conditions many larvae soon left their cases and dropped into the pan where they attached themselves to the bottom. The water was then poured out, and the larvae were scraped with a spatula.

Midge larvae were measured volumetrically in a graduated cylinder. Snails and dragonfly nymphs were placed on paper towelling to absorb excess moisture and were then counted and weighed.

3 LABORATORY TESTS

Laboratory tests were conducted in 40-litre aquaria containing tap water that was dechlorinated by passage through an activated charcoal filter. The water in each aquarium was aerated with compressed air. The aquaria were equipped with galvanized or aluminium wire screen covers to prevent the snails from crawling above the water line, where they would have been unavailable to the fish. These covers were suspended from the ends of the aquaria, and extended an inch (25.4 mm) or more below the water line. A small hole was made near one end of each cover for the aeration hose.

Feeding tests were conducted in these aquaria to determine the extent to which redears would eat snails under various conditions. From eight to 16 fish, with one fish per aquarium, were used in each test. The rate of feeding was based on the body weight of the individual fish. Each fish was weighed and fed a specified percentage of its initial body weight daily for five to seven days.

3.1 Utilization of snails by redears in the absence of other food

Redears having an average weight of 97.0 grams were offered snails at rates of 1, 2, 3, and 4 percent of their body weight daily for six days. Each feeding rate was replicated four times; however, one fish fed at the rate of 2 percent died during the test. In order to determine if redears utilized both genera of pond snails commonly found in Alabama, one-half of the fish fed at each rate received physid snails, and one-half received lymnaeid snails.

During this test, each fish was offered from 4.2 to 25.2 grams of snails. Natural mortality of snails was negligible and both genera of snails were eaten readily. Except for one fish fed at the rate of 4 percent, all fish ate all snails offered them.

In a similar experiment, higher rates of feeding were included. Redears that had an average weight of 107.2 grams were offered snails at rates of 1, 2, 3, 4, 5, 6, 7, and 8 percent of body weight daily for seven days. Each feeding rate was replicated twice, but one fish fed at the rate of 7 percent died during the test. Because both kinds of snails were eaten readily in the previous experiment, these snails were not segregated by species.

The maximum total weight of snails fed to a fish during this test was 69.3 grams. Natural mortality of snails was negligible except in two aquaria containing fish fed at rates of 5 and 7 percent. In these two aquaria natural mortality of snails amounted to 22.1 and 10.5 percent respectively of the total weight offered to the fish. None of the snails offered were refused by 13 of the fish, but not all were actually eaten since dead and occasionally living snails were found with all or most of the shells removed. The killing of the snail without consuming it usually occurred with higher rates of feeding.

3.2 Utilization of snails by redears in the presence of other natural foods

In the preceding experiments redears readily fed upon snails in the absence of other food. In order to determine the extent of snail consumption when other foods were available, redears averaging 36.2 grams in weight were fed snails and midge larvae daily for six days. Feeding rates, each replicated four times, were as follows: 2 percent snails; 2 percent snails plus 6 percent midge larvae; 4 percent snails; and 4 percent snails plus 6 percent midge larvae (Table I).

Redears that were offered snails alone at the rate of 2 percent daily ate 99.4 percent of them, but in the presence of midge larvae at the rate of 6 percent, snail consumption was reduced to 73.3 percent. When snails alone were offered at a rate of 4 percent, the fish ate 89.1 percent of them, but only 70.0 percent were eaten when midge larvae at the rate of 6 percent were also available. Although snail consumption decreased in the presence of midge larvae, it is considered significant that the fish continued to eat most of the snails.

The data obtained in this test had a serious limitation in that the extent redears fed on midge larvae was not determined. The lower utilization of snails in the presence of midge larvae was probably the result of the presence of this additional food; however, some fish ate considerably less than others. In this test, one fish offered snails only at the rate of 4 percent ate less snails than did six of the eight fish offered snails plus midge larvae. Whether part of this decreased utilization of snails was caused by listless feeding is not known.

Another factor that created a bias was the greater availability of the midge larvae as used in this test. In their natural environment, these larvae construct cases from sand and debris on submerged objects, often in places inaccessible to fish. Under such conditions, they are probably not as available to the fish as the midge larvae offered these fish.

Another natural food organism used with snails, and one allowing an estimate of its utilization by fish in aquaria, was the dragonfly nymph. Redears weighing an average of 90.8 grams were offered dragonfly nymphs at the rate of 10 percent plus snails at either 2 or 4 percent daily for five days. Each feeding rate was replicated four times.

During the course of this test, the remains of 431 dragonfly nymphs and 18 snails were removed. Many of the former were not intact, and all that remained of some of the latter was an empty shell. Observations indicated that dragonfly nymphs eaten by fish were consumed in their entirety, and that the shells of snails eaten were crushed and spit out. It was therefore concluded that these partially eaten nymphs and empty snail shells were the result of predation by dragonfly nymphs. In order to estimate the original weight of organisms eaten by dragonfly nymphs, an average weight was computed from the total numbers and weights of nymphs and snails used in this test.

With one exception, all fish ate more dragonfly nymphs than snails (Table II). Although the more abundant item was eaten in greater amount, the selection of food was not random. Snails made up 16.6 percent of the total food offered when fed at the rate of 2 percent; however, they comprised an average of 39.1 percent of the food eaten by

Table I

The utilization of snails by redears in aquaria

Daily feeding rate in percentage of body weight		Utilization of snails in percentage of total weight offered			
Snails	Midge larvae	Natural mortality	Not eaten	Eaten by fish	Average
2	0	0	0	100	
2	0	2.4	0	97.6	
2	0	0	0	100	
2	0	0	0	100	99.4
2	6	41.7	0	58.3	
2	6	5.6	0	94.4	
2	6	54.8	0	45.2	
2	6	4.8	0	95.2	73.3
4	0	5.1	38.5	56.4	
4	0	0	0	100	
4	0	0	0	100	
4	0	0	0	100	89.1
4	6	12.7	34.3	53.0	
4	6	33.3	0	66.7	
4	6	1.0	0	99.0	
4	6	9.0	29.5	61.5	70.0

Table II

The utilization of snails and dragonfly nymphs by redears in aquaria

Daily feeding rate in percentage of body weight		Total food in grams				Percentage of total food made up of snails		
		Snails		Dragonfly nymphs				
Snails	Dragonfly nymphs	offered	eaten	offered	eaten	offered	eaten	Average
2	10	13.0	12.0	66.0	27.8	16.6	30.2	
2	10	8.0	6.0	40.5	8.1	16.6	42.6	
2	10	10.0	9.9	51.0	15.1	16.6	39.6	
2	10	10.0	3.6	49.5	4.6	16.6	43.9	39.1
4	10	13.5	8.5	34.0	11.7	28.6	42.1	
4	10	18.0	7.3	45.5	7.4	28.6	49.7	
4	10	15.5	13.1	38.5	14.3	28.6	47.8	
4	10	21.5	15.0	53.5	12.3	28.6	54.9	48.6

fish fed at this rate. When fed at the rate of 4 percent, they comprised an average of only 28.6 percent of the total food offered, but 48.6 percent of the total food eaten. The "forage ratios" of snails and dragonfly nymphs, as proposed by Hess and Swartz (1940) were calculated and a significant difference was found indicating a preference for the former over the latter.

The importance of not determining the extent of midge larvae utilization in the preceding experiment is illustrated by Table II. One fish that was fed snails at the rate of 2 percent ate only 3.6 of the 10.0 grams offered it, which was considerably less than that eaten by the other three fish fed in like manner. Another fish that was fed snails at the rate of 4 percent ate only 7.3 of the 18.0 grams offered it, which was also considerably below average. Yet snails comprised a higher than average percentage of the diet of these two fish because of a low total consumption of food.

4 FIELD EXPERIMENTS

A series of 23 plastic pools that contained established snail populations was used to determine the effect of redears on snails in the presence of weeds. All pools contained several centimetres of soil in the bottom and the following plants: *Pithophora* sp.; naiad, *Najas guadalupensis*; pondweed, *Potamogeton diversifolius*; water hyacinth, *Eichhornia crassipes*; duck weed, *Lemna minor*; and water stargrass, *Heteranthera dudia*.

In order to determine if size of fish was a factor in the utilization of snails for food, two sizes of fish were used. The average weight of the larger fish was 99.7 grams and of the smaller fish 36.3 grams. Pools were stocked at each of the following rates: one large fish, three large fish, three small fish, and eight small fish per pool. Each stocking rate was replicated four times. Seven pools were designated as controls and received no fish.

The sides of these pools were translucent and allowed the passage of a considerable amount of light. Because of this, and the clearness of the water, snails on the sides of these pools could be readily seen and counted. The snails on the sides of each pool were counted immediately prior to the stocking of fish and daily afterwards for four days. The final observation was made on the tenth day after the fish were stocked. (See Table III below):

Table III

The average percentage reduction of snails on the sides of plastic pools

Number of pools	Number stocked	Average percentage reduction of snails at various intervals after the stocking of redears				
		Days : 1	2	3	4	10
7	0	12.1	22.2	30.4	29.7	38.1
4	1	84.9	94.9	97.2	99.4	99.2
4	3	80.6	96.0	97.2	98.4	96.9
4	3	93.2	96.8	98.3	98.9	99.4
4	8	98.9	99.6	99.3	100.0	99.7

Prior to the stocking of fish, the number of snails found in the 23 pools ranged from 30 to 207, with an average of 111.5 per pool. Although snails decreased in all pools during the 10 day test period, this decrease was especially prominent in the pools containing redears. On the first day after the fish were stocked two pools were found without any snails on the sides. The greatest number of snails observed at this time in any pool stocked with fish was 48. At the end of the 10 day test, the number of snails observed ranged from 0 to 9 in pools stocked with fish, and from 20 to 119 in the seven controls. No snails were found in eight of the 16 pools stocked with redears, and only one pool contained more than two snails. The average reduction of snails on the sides of these pools was 98.8 percent in the redear pools and 38.1 percent in the controls.

The lower stocking rate used was high enough to practically eliminate snails from the sides of these pools within 10 days. A statistical analysis of variance of the data obtained at this time indicated no significant difference in snail control between either the two sizes of fish or between the two stocking rates. The data obtained on the first day after fish were stocked also indicated no significant difference between the two stocking rates. However, at this time the smaller fish had reduced the number of snails to a significantly greater extent than had the larger fish. This difference may have been due to a temporary interruption in the feeding of some of the fish as a result of their being handled and placed in a new environment. An effect of this type would be more noticeable in the larger fish since smaller numbers were used.

Although no snails could be found on the sides of some pools stocked with redears, it is not considered that redears totally eliminated snails in any pool during this test. Upon close observation, a few snails could usually be found in the vegetation floating on the water's surface; however, they were almost completely eliminated in all cases upon venturing outside the heavy weed growths to the sides of the pools.

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FISH KILLS CAUSED BY PHYTOPLANKTON BLOOMS AND THEIR PREVENTION

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Abstract

Growths of species of *Microcystis*, *Anabaena*, and occasionally *Trachelomonas* and *Gymnodinium* that form dense concentrations or scums in surface waters have been a primary cause of fish kills in ponds. Dense concentrations of these algae absorbed heat from sunlight, causing a sharp rise in temperature of surface waters. This in turn caused shallow stratification and light winds stirred only the top waters. The heavy concentrations of algae absorbed and reflected sunlight and consequently insufficient light for photosynthesis penetrated to depths below 1m. Continuation of these conditions for approximately one week had the result that insufficient dissolved oxygen was present in waters below 1 m to support fish life. Subsequent upwelling of deeper oxygen-deficient waters caused distress or death of fish from lack of oxygen. Upwellings were caused by cold air masses, heavy winds or cold rains.

Microcystis was the most common cause of such kills. Partial eradication of this alga with copper sulphate allowed deeper light penetration, deeper stratification and distribution of oxygen to greater depths, thus removing danger of a fish kill.

While fish were in distress following upwelling, circulation and aeration of top waters with pumps or by stirring with boat and outboard motor prevented fish kills.

IX/E-12

MORTALITE DUE A LA PULLULATION DE PHYTOPLANCTON ET MOYENS DE PREVENIR CE DANGER

Résumé

On s'est aperçu que l'une des principales causes de mortalité des poissons en étang était la croissance d'espèces de Microcystis et d'Anabaena et aussi parfois de Trachelomonas et de Gymnodinium qui forment des concentrations denses ou une sorte de mousse dans les eaux de surface. Une forte concentration de ces algues absorbe la chaleur du soleil provoquant ainsi une élévation notable de la température des eaux de surface. Ce phénomène provoque à son tour une stratification peu profonde et les brises légères ne remuent que les eaux superficielles. De fortes concentrations d'algues absorbent et réfléchissent la lumière du soleil de sorte qu'au-dessous d'un mètre de profondeur, celle-ci n'est pas suffisante pour assurer la photosynthèse. Lorsque ces conditions se poursuivent pendant environ une semaine, il a été constaté que la quantité d'oxygène dissous dans l'eau au-dessous d'un mètre de profondeur était insuffisante pour assurer la vie des poissons. Lorsque, par la suite, des remontées d'eau profonde déficitaire en oxygène se produisent sous l'influence de masses d'air froid, de forts vents ou de pluies froides, elles entraînent chez les poissons des troubles physiologiques ou la mort par axphyxie.

Cette mortalité est due principalement à la présence de Microcystis. On a constaté qu'une élimination partielle de cette algue avec du sulfate de cuivre permettait une meilleure pénétration de la lumière, une stratification plus profonde et une répartition en profondeur de l'oxygène, rétablissant ainsi des conditions favorables à la vie des poissons.

On a pu sauver des poissons atteints de troubles physiologiques par la suite de remontées d'eau en aérant les eaux de surface et en activant la circulation à l'aide de pompes ou en les brassant avec un bateau muni d'un moteur hors-bord.

MORTANDADES DE PECES DETERMINADAS POR FLORACIONES DE FITOPLANCTON Y SU PREVENCION

Extracto

El desarrollo de especies de Microcystis, Anabaena y, en algunos casos, Trachelomonas y Gymnodinium que forman densas concentraciones o capas en la superficie de las aguas ha sido causa fundamental de mortandades de peces en los estanques. Las concentraciones densas de dichas algas absorben el calor del sol, determinando un rápido aumento en la temperatura de las aguas superficiales. Esto a su vez determina una estratificación somera de modo que los vientos ligeros solamente mueven las aguas de las capas superiores. Las concentraciones grandes de algas absorben y reflejan la luz del sol y por consiguiente a profundidades inferiores a 1 metro llega insuficiente luz para la fotosíntesis. La continuación de estas condiciones durante una semana aproximadamente dió por resultado que en las aguas por bajo de 1 metro no existía oxígeno disuelto suficiente para sostener la vida de los peces.

El subsiguiente afloramiento de aguas más profundas con deficiente oxigenación determinaron trastornos o la muerte de los peces por falta de oxígeno. Tal afloramiento de aguas inferiores fué determinada por masas de aire frío, vientos fuertes o intensas lluvias.

Microcystis fué la causa más corriente de tales mortandades. La eliminación parcial de esta alga con sulfato de cobre permitió que la luz penetrara más hondamente, una estratificación más profunda y una distribución de oxígeno a profundidades mayores, con lo cual desaparecería el peligro de la mortandad de los peces.

Mientras los peces registraban trastornos como consecuencia del afloramiento de aguas profundas, la circulación y aireación de las capas superficiales de agua mediante bombas o removiéndolas con botes provistos de motores fuerabordo evitaron la muerte de los peces.

The majority of ponds in Alabama impound stream waters or run-off waters by earthen dams constructed from hill to hill across a watershed. Maximum depths usually exceed 2 meters, with shallow water areas deepened to at least 0.6 metre. The average depth is between 1.5 and 1.8 metres.

1 DESCRIPTION OF FISH KILL

For many years, fish kills occurred occasionally in these ponds, the causes of which were unknown. Approximately 50 to 100 kills occurred each year in a total of 15,000 ponds. Some ponds had fish kills almost annually, whereas others 5 to 50 years old may have had one kill or none at all. Kills occurred in unfertilized as well as fertilized ponds, and in those receiving supplemental feeds. The kill occasionally affected only a particular species or only a particular size of fish. Sometimes all fish were killed, but more often only a part of the population died. Usually, by the time a biologist visited the pond a day or so after the kill, he found that no more fish were dying. Seining usually disclosed that remaining fish were in good condition and water analyses often indicated no reason why the fish died.

In many cases the water had a brown colour with most of the phytoplankton dead and there was no soluble phosphate in the top layer. The kills were obviously caused by lack of oxygen. It was postulated that the cause of plankton death was lack of phosphate, and for a number of years super-phosphate was added to surface water when fish were found in distress. This seemed to stimulate photosynthesis by the living plankton, with gradual increase in oxygen content. In many ponds, phosphate was kept on floats so that some would always be present in the surface water. Later information indicated that this did not prevent fish kills.

2 CAUSES OF FISH KILLS

Research during a period of years has shed much light on the sequence of events leading to this type of fish kills. The immediate cause of kills was the complete absence or low level of dissolved oxygen (DO), often accompanied by high concentrations of free carbon dioxide.

2.1 Type of phytoplankton growth

The sequence of events leading to a kill is as follows: A type of phytoplankton becomes dominant which, under certain conditions, rises to the surface as scum or a dense concentration in the top 0.6 m of water. Scum-forming algae usually have vacuoles filled with oil or a gas, which expands in warm water, lifting the algae to the surface waters. Blue-green algae, such as *Microcystis* and *Anabaena* belong in this scum-forming group; the former appears associated with the majority of fish kills. However, algae of the genera *Trachelomonas* and *Gymnodinium* have also been observed to be responsible for two kills.

2.2 Stratification and oxygen distribution

Once the algae have risen in dense numbers to or near the surface, they rapidly absorb heat from the sun, causing a sharp rise in temperature of the surface water (Beasley, 1963). A stratification then develops in which light winds stir only the hot surface water, thus preventing distribution of oxygen from upper to lower layers. At the same time, dense plankton in the upper layers absorb and reflect the sunlight so that inadequate light for photosynthesis penetrates to depths greater than 0.3 to 1.2 metres. Beasley (1963) found that oxygen was less than 1 ppm at depths where light had declined to 1 percent of incident radiation.

When this shallow stratification continued for several days or weeks as a result of hot sun and light winds, a condition developed where the surface 0.3 to 1.2 metres contained adequate oxygen for fish and the surface water was occasionally supersaturated with oxygen; however, inadequate or no oxygen was present at greater depths. This was a gradual development and in itself seldom caused distress since the fish moved into the upper waters where oxygen was adequate.

2.3 Upwelling and its causes

The trouble came with overturns, or upwelling of the oxygenless waters to the surface. This sometimes occurred over the entire pond causing complete kill, or only in local areas killing whatever sizes and species were trapped by the upwelling. At times, no fish were killed, but most were in distress at the surface because of inadequate oxygen following mixing of top and bottom waters.

There were various causes of upwelling. A sharp drop in air temperature caused colder surface water to drop toward the bottom and the oxygenless waters to rise to the surface. This is most likely to occur in late summer or early fall when the first cold air masses move southward.

Upwelling has often been caused by heavy winds that blow the surface waters towards the opposite bank, pulling deeper oxygen-deficient waters to the surface on the side from which the winds came. This cause of upwelling could be detected by chemical analyses for 6 to 12 hours following the event. Analyses on the leeward side of the pond showed no, or abnormally low oxygen in surface water. Analyses on the windward side showed abnormally high oxygen in deeper waters because of the oxygen-laden surface water being blown to that side and a reverse underwater current carrying it into deep waters.

Another cause of overturns was heavy cold rains falling on the pond surface and forcing deeper waters to the surface. When heavy cold rains fell on the watershed, cold stream water entered ponds, flowed along the pond bottom, and caused upwelling of oxygen-deficient bottom waters.

3 PREVENTION OF FISH KILL

3.1 When fish were in distress

When fish were found in distress because of upwelling waters, fish kills could usually be prevented by pumping water from 0.5 to 0.7 metre depths and throwing it with force at an acute angle against the pond surface. This caused a current of oxygenated water to move toward the far bank and an underwater circulation back to the pump, thus allowing oxygen-containing water to break up stratification and gradually bring oxygen to larger and larger areas. A pump delivering 19,000 litres of water per hour was sufficient for a 1-hectare pond. A pump delivering 114,000 litres per hour was effective in preventing kills over approximately 4 hectares.

A boat equipped with a 10 hp outboard motor, twisting and turning at high speed, required four hours to bring D.O. from 0.3 to 2 ppm to a depth of 1.5 metres in a 0.4 hectare pond.

3.2 Addition of phosphate to surface water

Often a pond had a series of overturns a few days apart before fish were found in distress. It was apparently prior overturns forcing the living plankton into oxygenless, lightless areas that had caused the "death" of plankton observed in some ponds. In such cases, often no soluble phosphate was found in surface waters following the overturn; phosphate was absorbed and/or precipitated on iron salts as these were oxidized to ferric salts by the oxygenated, downward moving surface water. At such times, addition of 10 to 20 kg super-phosphate per hectare broadcast over the surface water often appeared to stimulate photosynthesis and release of oxygen. When this was done during mid-morning hours with strong sunshine, many times sufficient oxygen was released to prevent a fish kill.

3.3 Control of phytoplankton scums

Since a primary cause of fish kills was surface scums, or excessive concentrations of *Microcystis* in surface water, it appeared better to kill part of the algal bloom so that light could penetrate to greater depths. When *Microcystis* became abundant, oxygen analyses were made daily. As long as oxygen was found below 1.3 metre there appeared no danger to the fish. However, when no oxygen could be found below 1 metre, the pond was in danger of a kill if conditions causing overturns developed. Killing part of the *Microcystis* with copper sulphate in one or two applications a week apart usually did result in deeper light penetration and distribution of DO down to 2 m or more. It was found very important to kill only part of the *Microcystis* at any one time. When enough copper sulphate was used to kill all of it, rapid decomposition removed the remaining DO and caused total fish kill.

The amount of copper sulphate recommended by Crance (1963) and Lawrence (1966) for use in waters with 25 ppm hardness, expressed as $CaCO_3$, was 800 g per hectare surface area. Copper sulphate is placed in cloth bags and tied about 10 cm under the water surface to a stake driven in the pond bottom. Copper sulphate gradually dissolves and water currents distribute it to various areas of the pond. One bag per 1 to 2 hectares is sufficient. Several treatments at one-week intervals may be necessary.

This method for controlling phytoplankton adds to the total BOD in the waters, and the nutrients may later by recycled to cause heavy scums. Biological control, using plankton-feeding fishes would appear promising and should be investigated.

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